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TEST ARRAY NUMBER 1 FOR MINE DETECTION EXPERIMENTS. (U)

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R. MAES

JANUARY 1980

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instrumentation or calibration units. Configurations of each element are documented, and data are presented on test site vegetation, soil conditions, and soil moisture content, also on meteorological conditions during periods when overflights were made for mine detection tests of various sensors. ←

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PREFACE

The objective of the minefield detection project is to determine the effectiveness of remote sensing systems and other methods of detecting and identifying mines, minefields, minelaying equipment, or minelaying operations, and to recommend continuing effort on the most promising methods.

Work under the project concerned with each of the concepts to be investigated is being performed in a sequence of four major tasks: (1) identification and screening of promising techniques; (2) preliminary systems analysis and definition of experimental or other data acquisition systems; (3) acquisition of critical data through experiment, literature survey, or access to SCI; and (4) evaluation of conceptual systems for technical performance and military usefulness.

This is one of a series of reports documenting technical effort and results achieved during the project. This report covers work performed under Task 3, Critical Data Acquisition, for planning and implementation of a test array located on a site near Ann Arbor, MI. The test array is required for testing and evaluating various types of minefield detection devices and systems.

Dr. J. Roland Gonano monitored the program for MERADCOM, Mr. Henry McKenney was the ERIM Program Manager, and Mr. Reed Maes supervised the installation of the mine array. E. Johansen, G. Suits, and D. Bornemeier of ERIM also participated in planning and setting up the mine array.

ERIM wishes to thank Dr. John Bennett and Mr. Gordon McInnes of TARADCOM who made arrangements for the military vehicles and radar decoys used in the mine arrays. Also, Mr. Robert Falls of MERADCOM provided advice on test site requirements and measured data on test site soil characteristics.



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TEST ARRAY NO. 1 FOR MINE DETECTION EXPERIMENTS

1

INTRODUCTION

In order to evaluate the technical effectiveness and operational utility of various methods of minefield detection, a program of analysis and experiment is being performed under the minefield detection project. Minefield detection techniques and systems which appear to have good potential for effectively performing this function are being selected under this project by a process of identification and screening. Selection of sensors and sensor features will be made considering types of surveillance systems presently in inventory or designs of systems in the R & D stage which can be reasonably anticipated to perform under battlefield conditions.

An important part of the overall program is the acquisition of data needed to answer critical questions concerning the usefulness of selected techniques. Task 3 is intended to cover data acquisition involving sizable efforts which will be implemented after sponsor review and approval.

In many cases, the acquisition of critical data requires the conduct of flight tests or field experiments to ascertain the capability of selected sensors to detect and/or identify individual mines, minefields, minelaying equipment, minelaying activities or ancillary equipment, such as field fortifications, likely to be associated with the presence of mines. The criteria for success in evaluating the mine detection and identification capability will be essentially the probability of detection or identification under anticipated battlefield conditions. False alarm rates are also of importance.

In order to conduct realistic tests of this capability, the presence of mines or associated equipment must be simulated under circumstances representative of anticipated operational conditions. For this purpose, one or more test arrays are needed to simulate the essential elements of various scenarios, including various types of terrain likely to be encountered. They must be designed to accommodate both direct and inferential modes of minefield detection. Ground-based sensors as well as airborne sensors must be accommodated by the test facilities.

The scenarios selected for analysis and testing of minefield detection techniques are based on combat operations in the European theater, and in particular in three areas of West Germany: the North German Plain, the Fulda Gap, and the Hof Corridor. The climate and terrain for these areas have been studied under another task of this project, and reports documenting these characteristics have been prepared (Refs. 1 and 2).

The test site described in this report has characteristics of soil, vegetation, topography, etc., representative of the North German Plain. The weather, soil, and vegetation data of the test site area were monitored during the program and are included as part of the data base.

2
TEST SITE DESCRIPTION

2.1 TEST SITE REQUIREMENTS

In order to provide a basis for selection of a suitable test site or sites for the installation of the test array of mines and related equipment, a set of requirements was developed. The following list describes the major requirements for test sites representing the characteristics of the three areas of West Germany mentioned above.

- (1) The sites should have soil characteristics, moisture content and vegetation representative of Eastern Europe.
- (2) There should be a variety of background including flat land and rolling terrain with vegetation and crops.
- (3) The sites should be representative of tactical situations with surface and buried mines of various types. There should be an opportunity for both direct and inferential detection.
- (4) The sites should be in a location suitable for both airborne and ground-based data collection.
- (5) The sites should have sufficient security to protect any military equipment needed for the experiment.
- (6) At the same time, the sites should be accessible to the project personnel.

For Test Array No. 1, certain additional requirements were specified.

- (7) The test site should be located near Ann Arbor, MI to enable the ERIM staff to perform ground operations and conduct flight tests from its aircraft efficiently. In addition to flight tests especially scheduled for the project, it might also be possible to acquire additional sensor data as the ERIM aircraft passes over the test site on its way to other test sites. This would provide much added data at little incremental data acquisition cost.
- (8) A non-military rural atmosphere was desired in order to allow for a realistic setting for the measurement program, a setting where farming and cultivation practices could continue in a reasonably uninterrupted manner while a military scenario could develop without causing concern to the local population.

Test Array No. 1, which is fully described in this report, meets these requirements for a site representative of the North German Plain. Additional test arrays, if implemented, would be selected to be representative of the other two areas mentioned.

2.2 TEST SITE SELECTION

The initial investigation was directed toward setting up two test sites -- one that satisfied the desired flat terrain characteristics and another in close proximity that satisfied the rolling terrain requirements. The effort was soon narrowed to selecting a single site with flat terrain.

The selection process involved examining good topographic and soil identification maps in the two-county area of interest near Ann Arbor. The process also required having a working knowledge of the rural, industrial, and governmental developments in the region that might make suitable sites. Through this process, eight locations were selected for possible use, two adjacent to Willow Run Airport, a fence-enclosed automotive testing facility, and five rural sites. Many of the sites had to be eliminated because of availability, security, or soil conditions.

One of the sites considered in detail is located about 7 mis. southeast of the center of Ann Arbor, and about 10 mis. west of Willow Run Airport, where the ERIM Flight Facility is located. The site is approximately rectangular with dimensions of roughly 200 m by 400 m. The shape of the planned test array could be modified slightly to fit these dimensions. The area is flat grassland, presently used for hay crops. However, this site was rejected because it was found to have soil characteristics not fully representative of West German terrain of interest.

The site finally selected for the first test array has characteristics representative of the North German Plain. The twenty acre site is situated on the 185 acre Warner farm in Pittsfield Township of Washtenaw County approximately one mile west of Ann Arbor Airport. The area is shown in Figures 2-1 and 2-2. The twenty acres is at the southwest corner of the farm and is approximately one-half mile from any public road. It is accessed by a private lane. After acquisition of the site, a gate was installed to limit unwanted traffic in this lane. The area is typical Michigan countryside and the field is bounded by a wood lot on the west side and a portion of the south side, and bounded by the lane and a drainage ditch on the east side. The area was planted in alfalfa a few years prior to its use as a test site so the vegetation is a mixture of alfalfa with other grasses. The soil types include Matherton sandy loam and Sebawa loam.

Soil maps of this site were obtained and soil samples were forwarded to MERADCOM for analysis. MERADCOM reviewed the site characteristics and reported that the soil types were suitable. Once approval of the site characteristics was received, ERIM proceeded with arrangements for leasing the site.



FIGURE 2-1. LOCATION OF TEST ARRAY

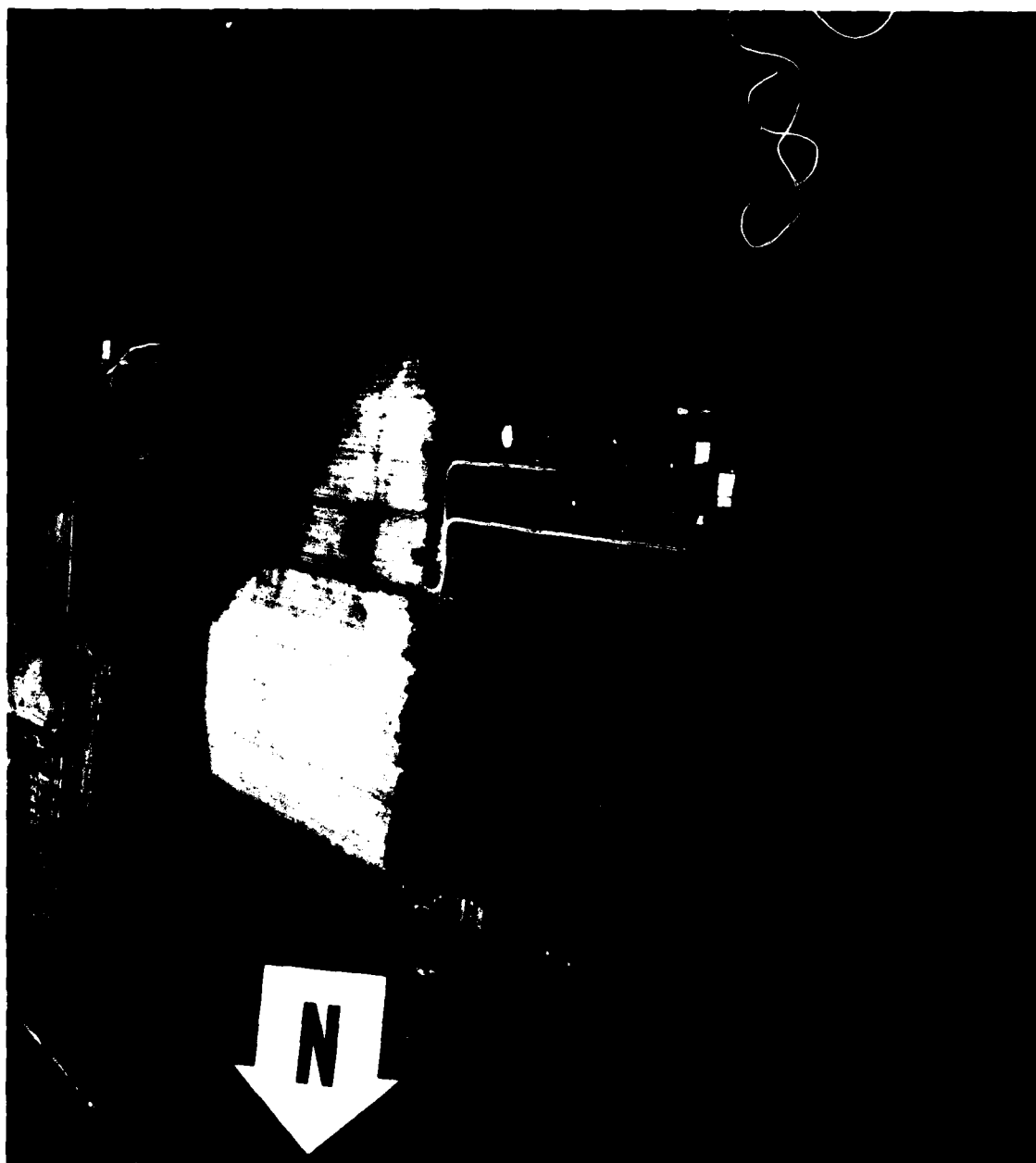


FIGURE 2-2. AERIAL PHOTOGRAPH OF TEST ARRAY AND ENVIRONS

3
TEST MINE PROCUREMENT

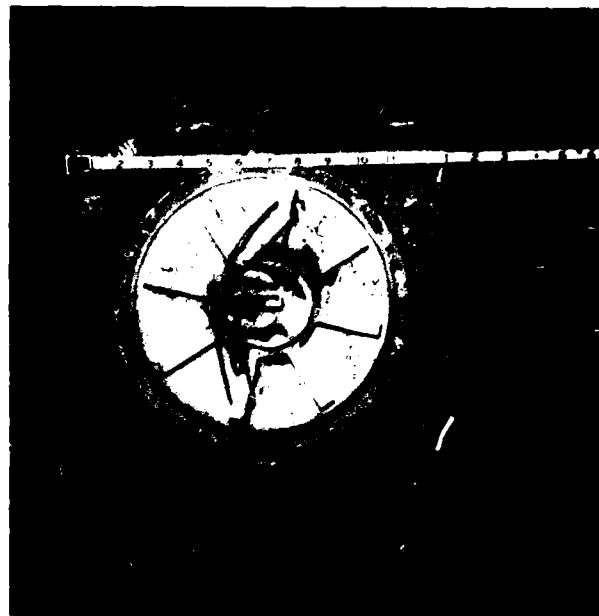
Four types of mines were used in the test array as shown in Figure 3-1. They were the M-15, M-19, PM-60, and artillery scatterable mines. Plastic PM-60 and metallic TM-46 Russian mines were replaced in our tests with simulated PM-60's procured under this contract and metallic U.S. Army M-15's which are roughly equivalent to the TM-46. Supplementary data to show the equivalency of the simulated PM-60 to the real PM-60 and also the M-15 U.S. antitank mine to the TM-46 Russian equivalent are presented in Appendix A.

It was originally proposed that dummy mines to be used in the test array would be supplied as GFE. However, to supplement mines available on a GFE basis, it was later decided that ERIM would undertake procurement of the mines as a separate task in the project. Plans for obtaining 450 dummy PM-60 mines were developed. The physical characteristics of the mines (size, shape, metallic content, dielectric characteristics of non-metallic materials, thermal characteristics, surface spectral characteristics) were specified by ERIM in sufficient detail so that solicitation of bids for the mines could proceed. For this purpose, spectral measurements were made on the coating of the mines. A sample of a metallic fuze was obtained from MERADCOM so that its characteristics could be accurately simulated.

One problem addressed in performing the test program was the selection and use of suitable paint for the test mines. ERIM worked with Dr. Fred L. Lafferman (DRDME-VO) at MERADCOM to specify paint which closely simulates the Soviet PM-60 paint. Dr. Lafferman analyzed a paint chip from the PM-60 sent to him by ERIM and informed ERIM that TTE-529 olive was satisfactory for measurements at 1.06 and 10.6 micrometers. ERIM obtained standard Army paint (529c) from the U.S. Army Tank-Automotive Research and Development Command



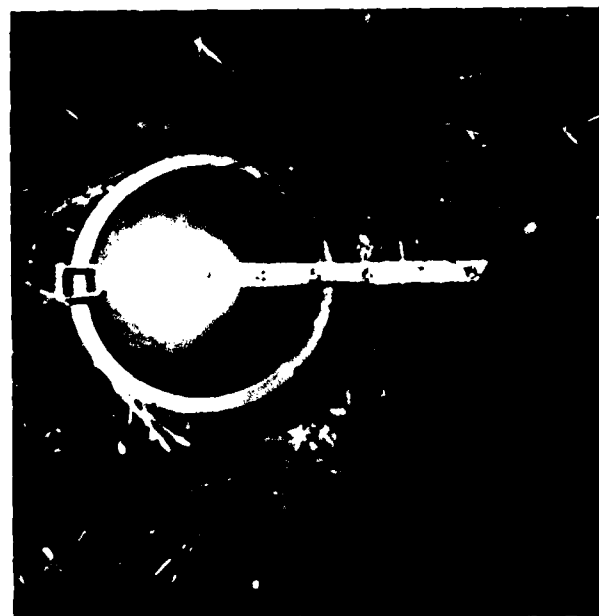
(A) M-15 Metallic



(B) M-19 Plastic



(C) PM 60 Plastic



(D) Scatterable Mines-Metallic

FIGURE 3-1
MINES USED IN TEST ARRAY

(TARADCOM) and used it to paint the four dummy PM-60 mines used in early tests.

Based on recommendations received from Dr. Lafferman, ERIM ordered and received paints that simulate those used for Russian mines. These paints were obtained from Ameron Industry Coatings of Wichita, KA. TTE 529 olive paint was used with the plastic mines, and TTL 20 lacquer paint was used with the metal mines.

Quotations were obtained from potential suppliers of dummy mines and after a period of negotiation, one of them was selected. Discussions between ERIM and MERADCOM were then held concerning a supplement to the existing contract which would enable ERIM to obtain 450 simulated PM-60 mines for the experimental program. Pending approval of this add-on, ERIM in April 1979 authorized the vendor to proceed with fabrication of tooling for the mines at a cost of \$2,100.

A sample mine made from production tooling was supplied to MERADCOM for comment and approval. The requirement for fuzes and fuze wells in the first 190 mines was deleted. It was decided that only 20 mines would be supplied with fuzes and fuze wells.

Based on this review and approval, ERIM authorized the vendor to fabricate 190 mines for delivery on or before 6 July. This delivery date was selected to allow adequate time for installation of the mines in the array prior to conducting tests on the spotlight radar.

Of the 190 mines fabricated, 150 mines were used in the array. The remaining 40 were sent to Yuma for MERADCOM tests of a mine detector scheduled for mid-July, in accordance with MERADCOM's request.

Arrangements were also made through the Selected Ammunition Project Office of Picatinny Arsenal to obtain 50 inert scatterable anti-vehicular mines. When these mines were received, they were painted for use in the test array.

About 500 mines were obtained from Ft. Huachuca for use in testing. These were predominantly metal M-15 mines, but some plastic M-19 mines were included. On receipt, 100 of the metal M-15 mines were painted field green and marked as inert mines for use in the array.

After tests were conducted at Test Array No. 1 using the above mines, it was decided that the additional simulated PM-60 mines to reach a total of 450 were not needed, and plans for their fabrication were not implemented.

TEST ARRAY

The general layout of the test site and its surroundings is shown in Figures 4-1 and 4-2. It is basically a standard twenty acre field that is 1/4 x 1/8 mile in size, roughly 200 m by 400 m. The total area is divided into 16 rectangular areas or elements, each 50 by 100 m in size. As discussed in Section 5, each of the elements is used for installation of dummy mines, either surface or buried, in specific configurations, for the location of various ancillary military items, as an undisturbed control area, or for the location of special instrumentation or calibration units. Section 4 describes the test site vegetation, soil conditions, and soil moisture content.

4.1 TEST SITE VEGETATION

The test site vegetation was, generally speaking, alfalfa plus mixed grasses. The general area to the south and west were bordered by a mature hardwood forest and to the east by an access lane and hedge row consisting of trees and shrubs up to 50 years old. The alfalfa field continued beyond the north side of the test site. There was a fence and hedge row in the E-W direction between elements 1-4 and 5-8 that contained trees and bushes that were at least twenty years old. In addition to this, there were four large mature oak trees located in the alfalfa field.

The alfalfa in elements 1-4 was a recent planting (3 years old) and had fewer weeds and miscellaneous grasses in it than the alfalfa in elements 5-16 (6 years old), although it was evident by some of the uneven growth in elements 5-16 that some reseeding had taken place in the last few years. The field experiments were set up so that no digging or major disturbance were made in elements 1-4; this area was used for surface mines only and was mowed during the week



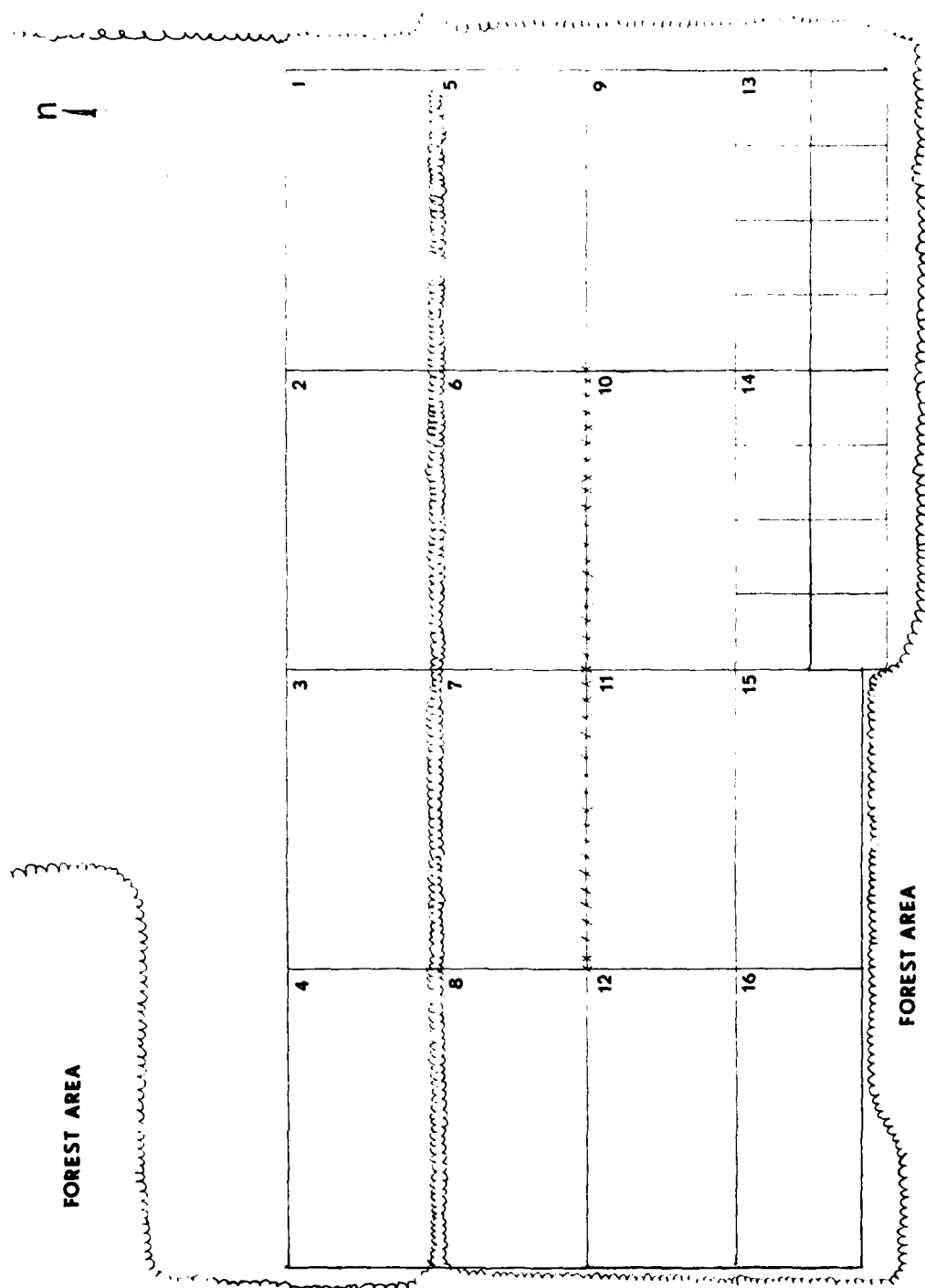


FIGURE 4-2. ARRANGEMENT OF TEST SITE ARRAY ELEMENTS

of July 4th. The alfalfa in elements 5-16 was mowed the second week in June since it was in this area where most of the test site preparations were required such as calibration arrays, buried mines, etc. For this reason the vegetation was taller by about 4 to 7 in during the data taking phases of July and August in the 5-16 elements. Figure 4-3 shows the average vegetation heights plotted during the experimental program. Figures 4-4 A, B, & C show the general vegetation in elements 1-4 and 5-16 respectively.

The vegetation density in elements 1-4 was fairly uniform, whereas the density in elements 5-16 tended to be streaked in the E-W direction because of variations in the reseeding. These streaks can be seen in some of the imagery and could easily be confused as vehicle path marks. The actual height of the vegetation was fairly dependent on weather conditions once the alfalfa was over 18 in high. On rainy days or when there was excessive moisture on the foliage, there was considerable matting so that the measured height would be less than 1 ft.

4.2 SOIL CONDITIONS AND SOIL MOISTURE CONTENT

The terrain of the test site contains two main soil types, Matherton sandy loam and Sebawa loam. It has a few small stones but no noticeable rocks of significant size. There is a large drainage ditch on the eastern edge of the site and the wooded area to the west is slightly lower in elevation than the open field. There is a very gentle slope downward to the western one-third of the site so that any water accumulation on the field tends to be at the west end.

A number of soil samples were delivered to MERADCOM for evaluation of soil constituents and moisture content. The soil texture ranging from very fine sandy loam to heavier loam was representative of the central region of West Germany.

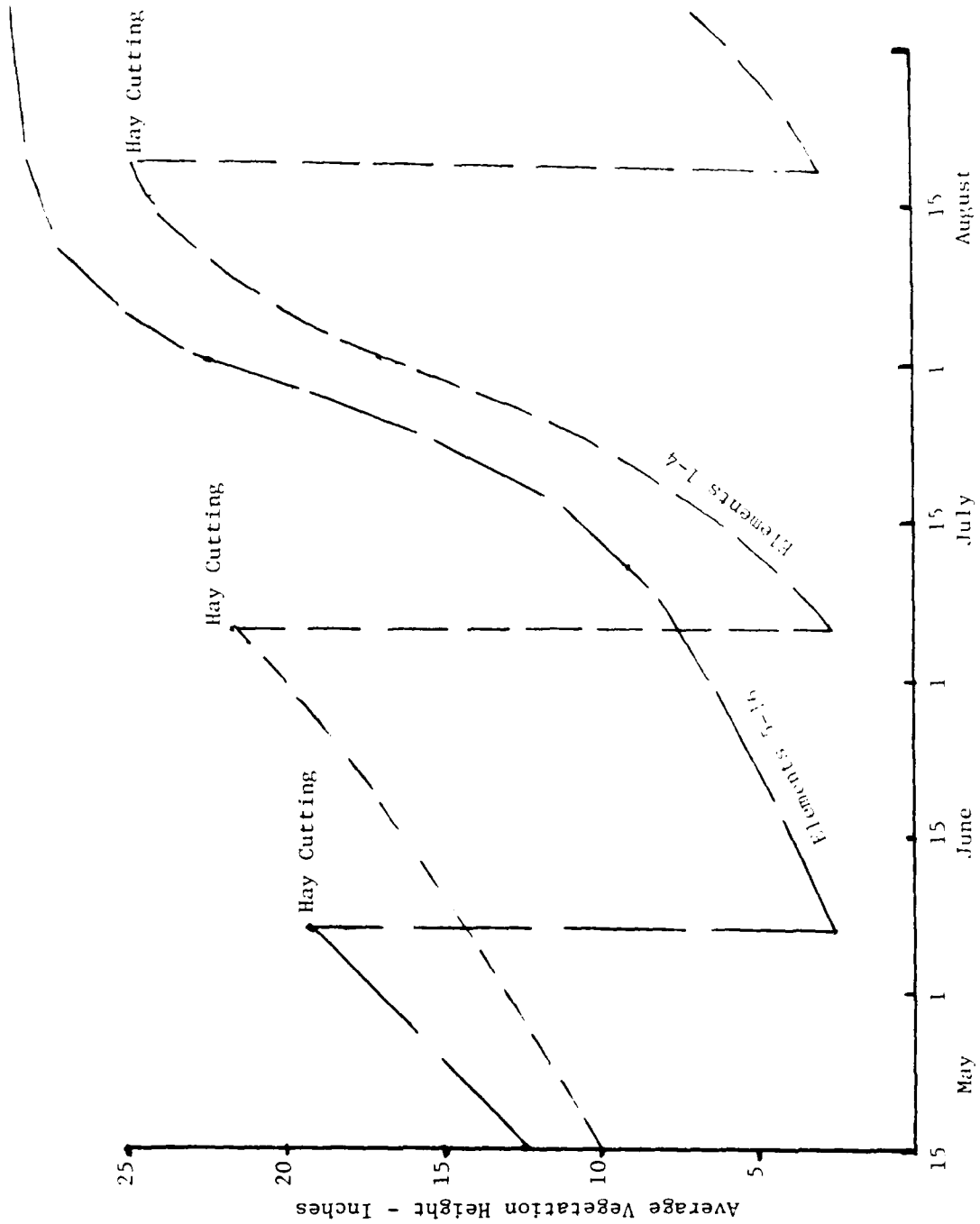


Figure 4-3. Test Array Vegetation Height



Moisture content measured in late March was found to be 24% and again in mid-July was found to be 18%. These numbers are higher than normal for Michigan because of the abnormal amount of rain that occurred during the spring and summer, but would be considered fairly typical for West Germany.



(A) Elements 1&2 Mid July



(B) Elements 1&2 Early August



(C) Elements 5&6 Mid July

FIGURE 4-4
TEST SITE VEGETATION

5
TEST ARRAY

Figure 5-1 is a layout of the test array. The approximate 200 by 400 m area is divided into 16 rectangular areas or elements, each 50 by 95 m in size. The 16 test elements were utilized as follows:

- (1) 11 elements of mine configurations
- (2) 2 elements of military vehicles and components
- (3) 2 elements of calibration and instrumentation array
- (4) 1 empty reference element

The test site was surveyed and marked with sufficient stakes and lines to achieve 2 ft location accuracies within the elements. The element corners were implanted with 5 ft steel fence posts, superimposed with 2 ft x 2 ft horizontal white fiber boards and radar corner reflectors.

5.1 TEST MINES

Test elements 1, 2, 3, 5, 6, 7, 8, 9, 10, 12, and 16 were used for various test mine configurations. The objective was to have as many variations as practical that represent real field conditions.

5.1.1 SURFACE MINES

Elements 1, 2, and 3 were used to distribute surface mines of the three mine types that were available in adequate quantities (M-15, M-19, and PM-60's), whereas element 4 is empty and undisturbed. The fields were as undisturbed as practical to simulate field conditions. Figure 5-2 shows the dimensions within these elements that mark the locations of the surface mines. Whenever conditions permitted, a vehicle loaded with fresh mines was

stationed in element 2 during flight tests for the purpose of substituting approximately ten mines for those that had been stabilized thermally.

5.1.2 HAND-BURIED MINES

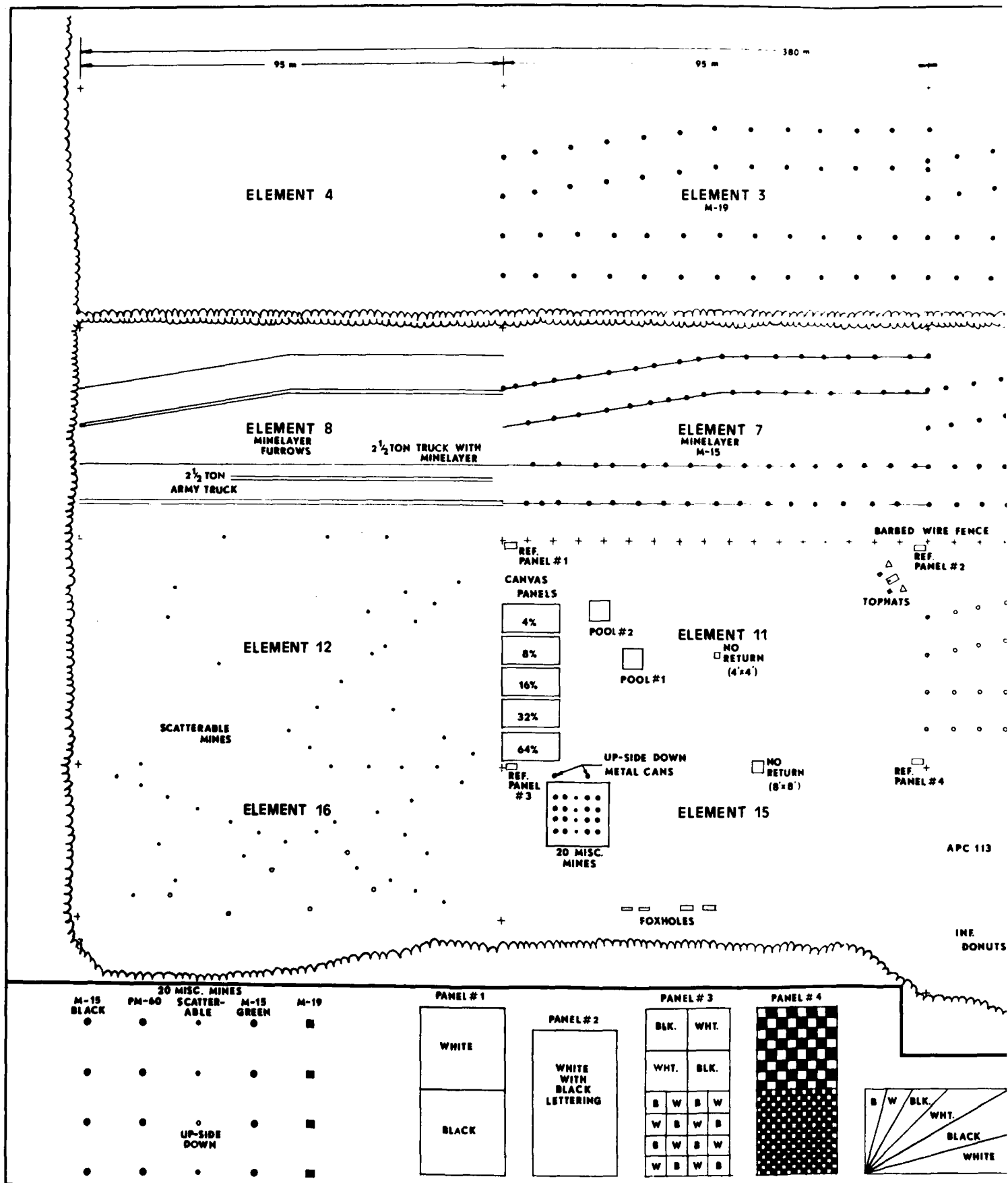
Test elements 5, 6, 9, and 10 were variations of hand buried mines. Figures 5-3, 5-4, & 5-7 show the dimensional locations of the M-15's, PM-60's in elements 5, 6, and 10; Figure 5-6 shows the dimensions of the minecord M-15's used in element 9.

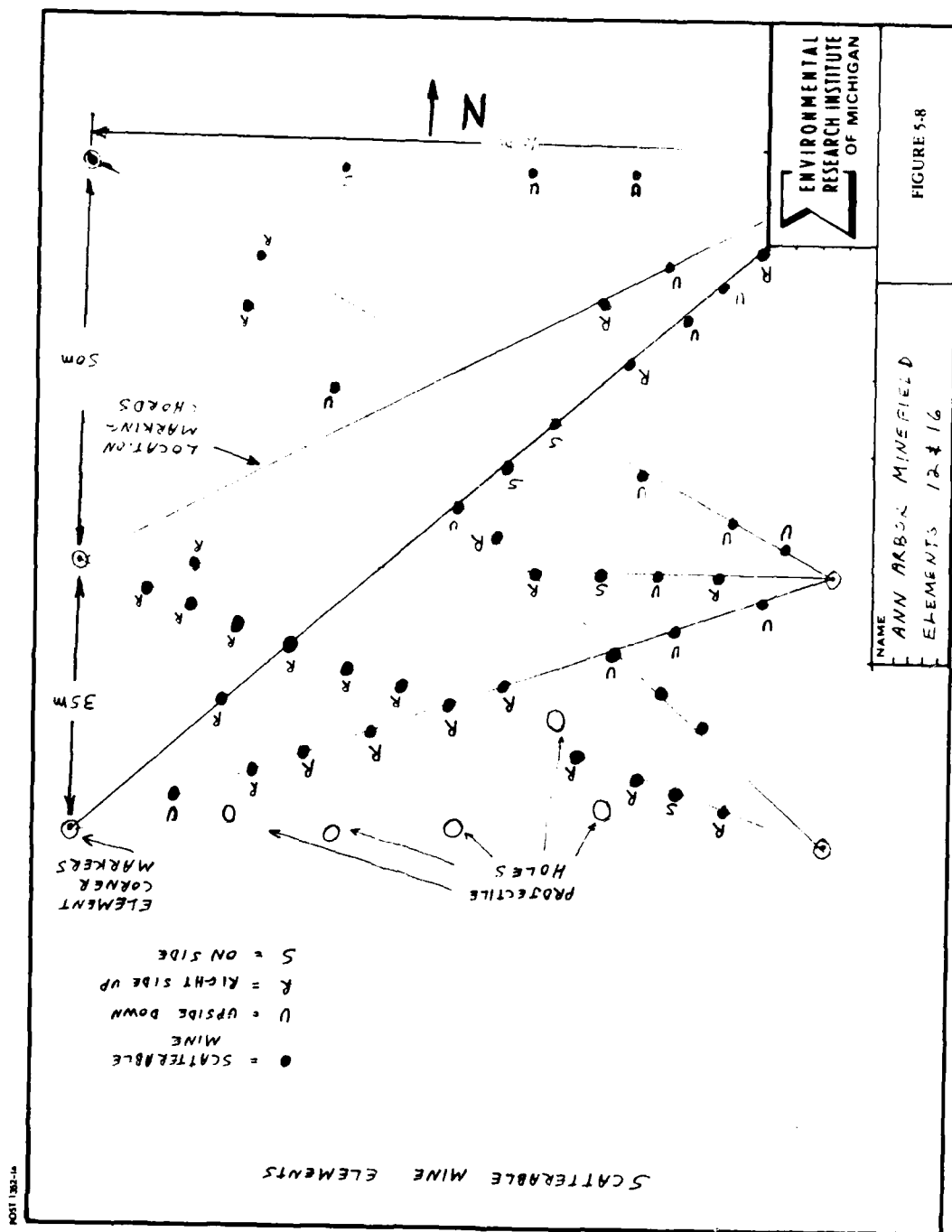
5.1.3 MINELAYER BURIED MINES

Elements 7 and 8 were devoted to variations in machine laid mines. Element 7 was planted with M-15's using the GFE minelayer plow pulled by a 2-1/2 ton truck. The element had four lines of mines as shown in Figure 5-5. Two of these lines were smoothed somewhat with shovels to help conceal the furrows and the other two lines were left as plowed by the minelayer. The minelayer did not distribute the mines at uniform distances in the element. The dimensions in the figure show where the actual locations of the mine were. Element 8 was plowed with four furrows but no mines were buried in this element. In element 8 two of the furrows were left uncovered and the other two had the furrows recovered. The layout for element 8 is the same as for element 7.

5.1.4 SCATTERABLE MINES

Elements 12 and 16 were used for setting up the scatterable mines. Figure 5-8 shows the locations of the scatterable mines and the impact holes of the delivery projectiles. Scarf marks left by the mines as they impact and roll to a resting place were simulated near each mine. Since the mines are not symmetrical, notations were made designating the orientation when they finished rolling. The test elements were set up as if 5 shell projectiles were delivered in the test zone.





5.2 MILITARY VEHICLES AND INFERENTIAL CHARACTERISTICS

In addition to test mines, other items of military equipment were obtained and used in the test array. A minelayer was obtained for use, and was generally located in the element with furrows. In addition several military vehicles and decoys were obtained from the U.S. Army Tank-Automotive Research and Development Command (TARADCOM). The vehicles included an armored personnel carrier, a 2 1/2 ton truck, a jeep, and an M-60 tank. The decoys were mainly to simulate radar characteristics and consisted of metalized inflated balloons, various shell casing configurations, a camouflage net and prefab boxes.

Other identifying features that appear in some minefields were incorporated into the scene. A 200 m barbed wire fence was installed on the south edge of the buried mines in elements 6 and 7. The vehicle traffic involved in the logistics of setting up the various elements caused lanes and ruts to be formed in the field. Other tracks caused by the heavy military vehicles were also evident in the field. Also foxholes were incorporated near one of the elements where decoys and military vehicles were situated.

5.3 GROUND TRUTH

As an aid in the analysis and interpretation of flight test imagery or ground-based imagery collected for the test array, it is essential that extensive ground truth be collected before and during each test. On site photos were then taken of the test array during the program. Two sets were made, one for MERADCOM and the second for ERIM. Equipment and facilities were provided at the test array for collection and recording of the following types of information:

5.3.1 WEATHER INFORMATION

Data were collected at the site for the following parameters:

Air temperature

Precipitation

Wind direction

Wind speed

Cloud cover data (percent cover, cloud types, cloud heights)

In addition to measurements made at the test array, data were collected from other sources. The National Airport Weather Sequence was collected from nearby University of Michigan Weather Station located in Ann Arbor. (See Appendix B).

5.3.2 TERRAIN CONDITIONS

Data were also collected on the following terrain conditions:

-Soil moisture content

-Vegetation

 Cover types

 Plant height

 Plant density

5.3.3 CALIBRATION DATA

Certain types of ground-based data are required as a means for calibrating the airborne sensors under test. These items were mainly contained in element 11.

Calibration data for temperature sensitive sensors was provided by the use of special temperature calibration surfaces and devices. Several temperature reference panels were placed within the test array. Each panel was large enough to cover several pixels in the sensor image. A water pond of known temperature was also used for this purpose. A small heat exchange panel was constructed consisting of adjacent surfaces of black, white, and gray. Thermometers were placed behind each surface. The device was then placed on the surface of the ground. The three surfaces were several inches above the ground surface and effectively insulated from the surface thermally. The temperature of each panel was recorded before and during the flyover. A solar cell covered by a diffusing

screen was used to measure short wave daylight, and air temperature in the shade was also measured. This information is sufficient to extract the values of basic parameters which can be used in thermal modeling to extrapolate the test results to other conditions of environment and weather.

For tests of photographic or thermal imaging systems, gray-scale reference canvases and spatial resolution panels were placed in the test array. The spatial resolution panels can also be used for checking the spatial resolution of thermal imaging systems.

For calibration of radar systems, radar retroreflectors of known radar cross section were placed at various points in the test array. The radar targets included corner reflectors at each of the element corners throughout the array, metal cylinders on metallic ground planes (top hats), large surface no-return areas (metallic sheets) and large metal upside down cylinders ranging in size from standard 5 gallon to 55 gallon drums.

5.3.4 GROUND BASED IMAGERY

Thermal images of mines and background areas were obtained with a ground-based thermal imaging system. In addition, ground-based photography was obtained to record the exact conditions existing at the time of each overflight.

In order to investigate the ability to detect mines from the ground, other tests were conducted by obtaining color movie coverage from a jeep as it moved into and through a minefield. This coverage simulated typical ground observation of a minefield from a vehicle. Similar coverage at eye level for a walking man was also obtained.

TEST CONDITIONS FOR FLIGHT TESTS

Test Array No. 1 was used in a series of flight tests conducted during July and August 1979. These flights included the following:

- (1) Handheld Minicam, Piper Cub - 19 and 20 July.
- (2) KS-87B photographic coverage, RF-8G - 12 July, 27 July (Also attempted 25 July).
- (3) FLIR and KA-76 photographic coverage, Mohawk aircraft - 19 July, 4 flights: 6 AM, 10 AM, 4 PM, and 9 PM; 20 July, 2 flights: 10 AM and 12:30 PM.
- (4) Passive infrared coverage with AAD-5 scanner, RF-4C - 1 August.
- (5) Spotlight radar coverage with ERIM CV-580 aircraft - 1, 2, and 3 August.

In this section, test conditions are recorded for each of the above flights. The data presented include the location of mines, military equipment, instrumentation, etc., on the test array (Figures 6-1 through 6-12) and weather data. (Tables 6-1 through 6-4). Table 6-5 shows the times at which the various elements were completed in the test array.

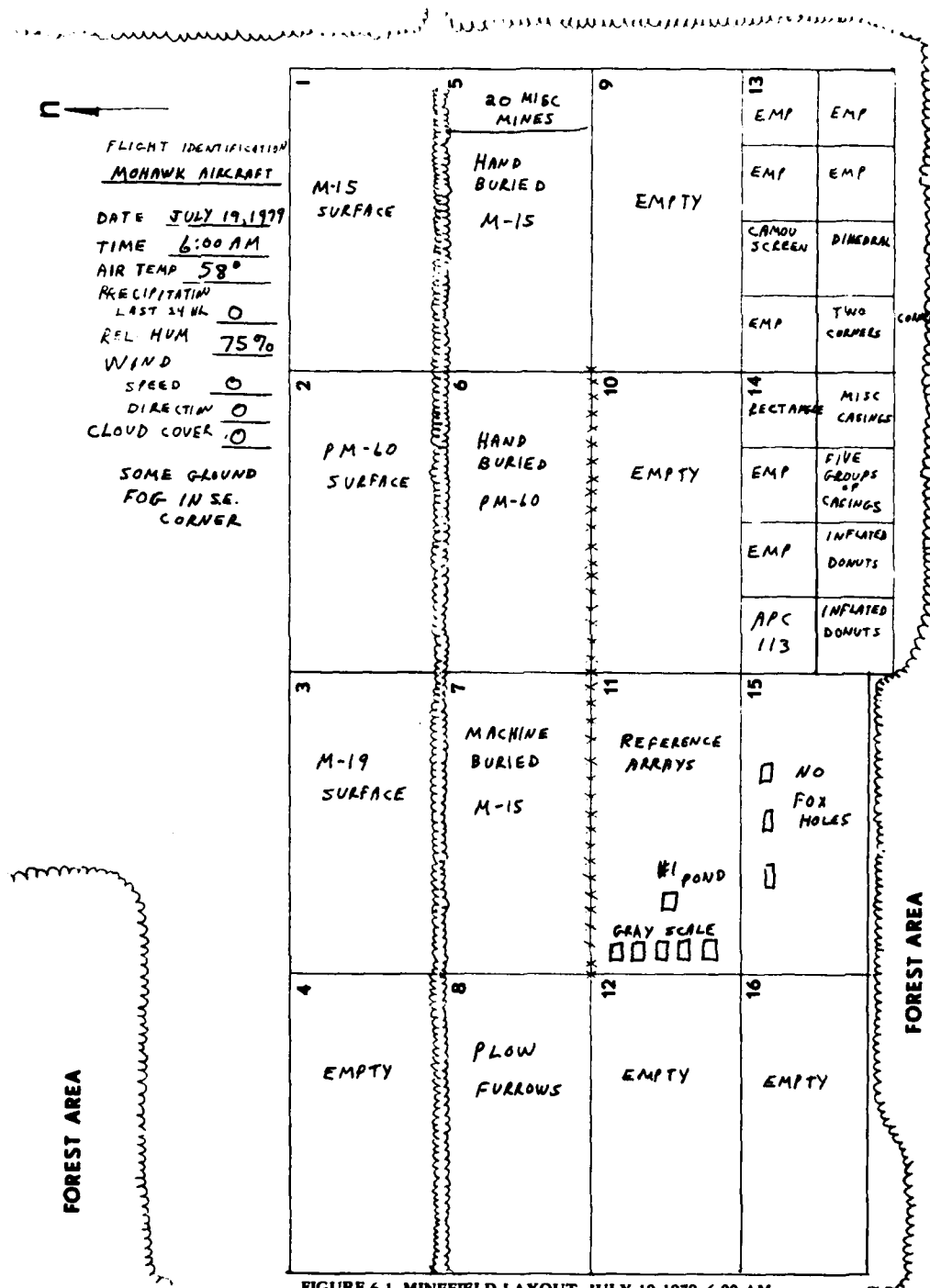


FIGURE 6-1. MINEFIELD LAYOUT, JULY 19, 1979, 6:00 AM



FLIGHT IDENTIFICATION
MOHAWK AIRCRAFT

DATE JULY 19
TIME 10:00 AM
AIR TEMP 74°
PRECIPITATION
LAST 24 HR 0
REL HUM 50%
WIND
SPEED 10
DIRECTION S.W
CLOUD COVER 0

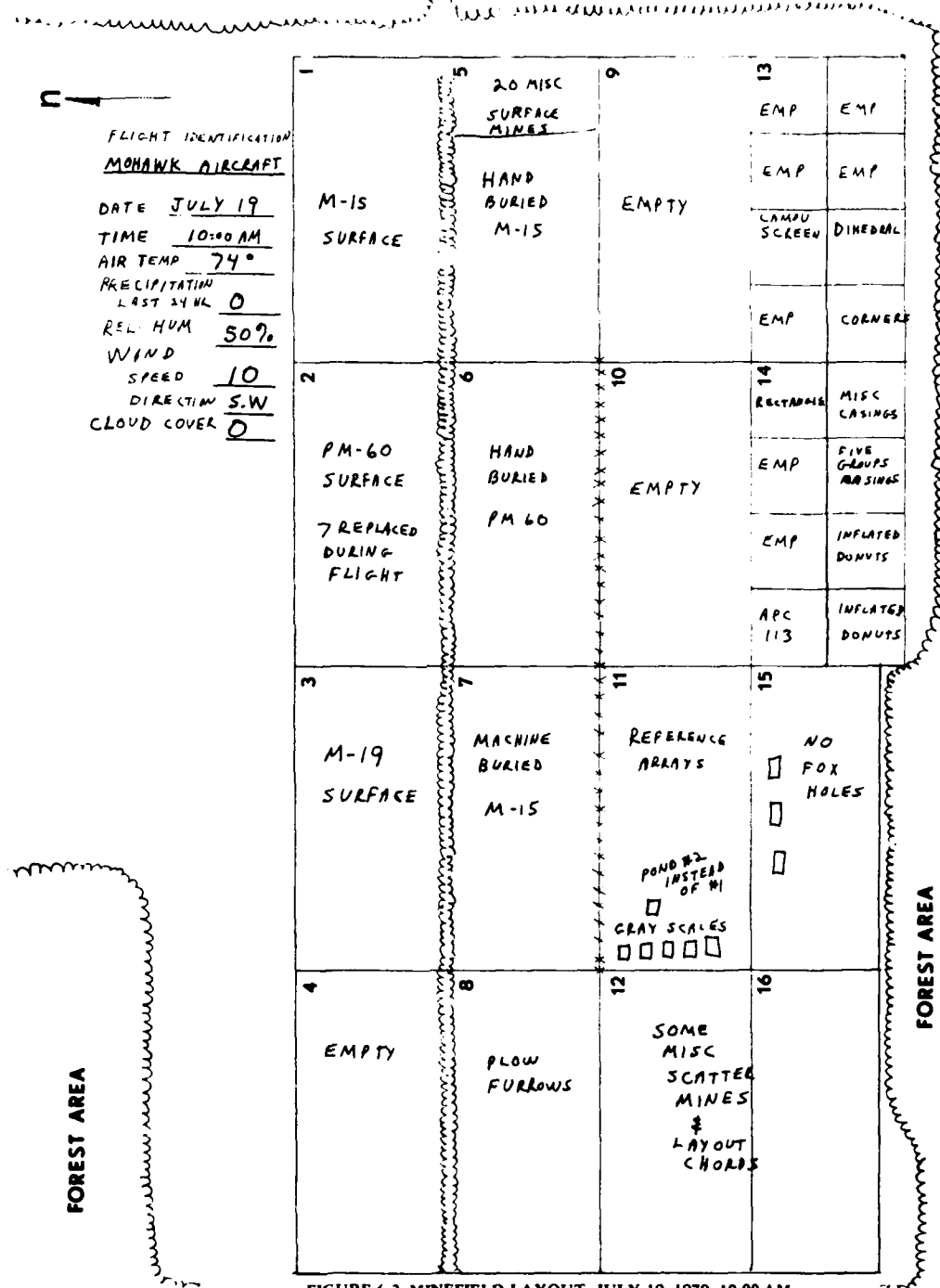


FIGURE 6-2. MINEFIELD LAYOUT, JULY 19, 1979, 10:00 AM

FLIGHT IDENTIFICATION
MOHAWK AIRCRAFT
 DATE JULY 19
 TIME 4:10 P.M.
 AIR TEMP 82°F
 PRECIPITATION 0
 LAST 24 HR
 REL HUM 56%
 WIND
 SPEED 5
 DIRECTION SE
 CLOUD COVER 0

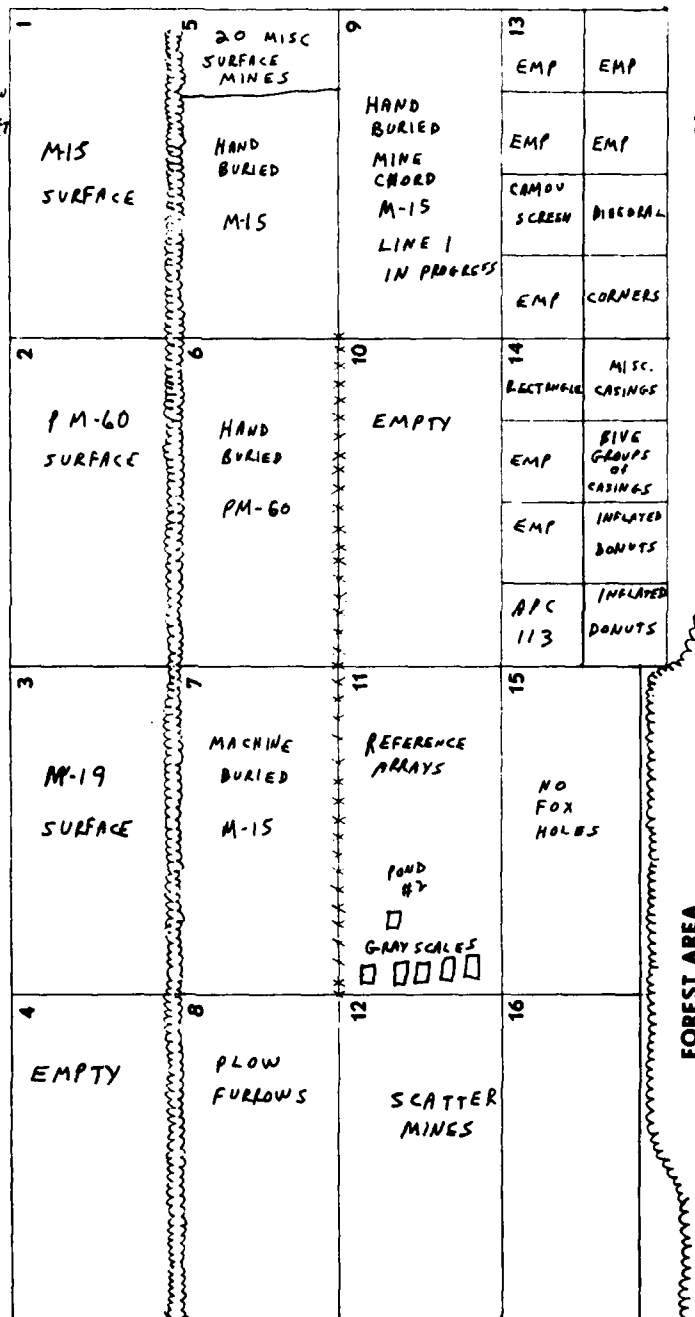
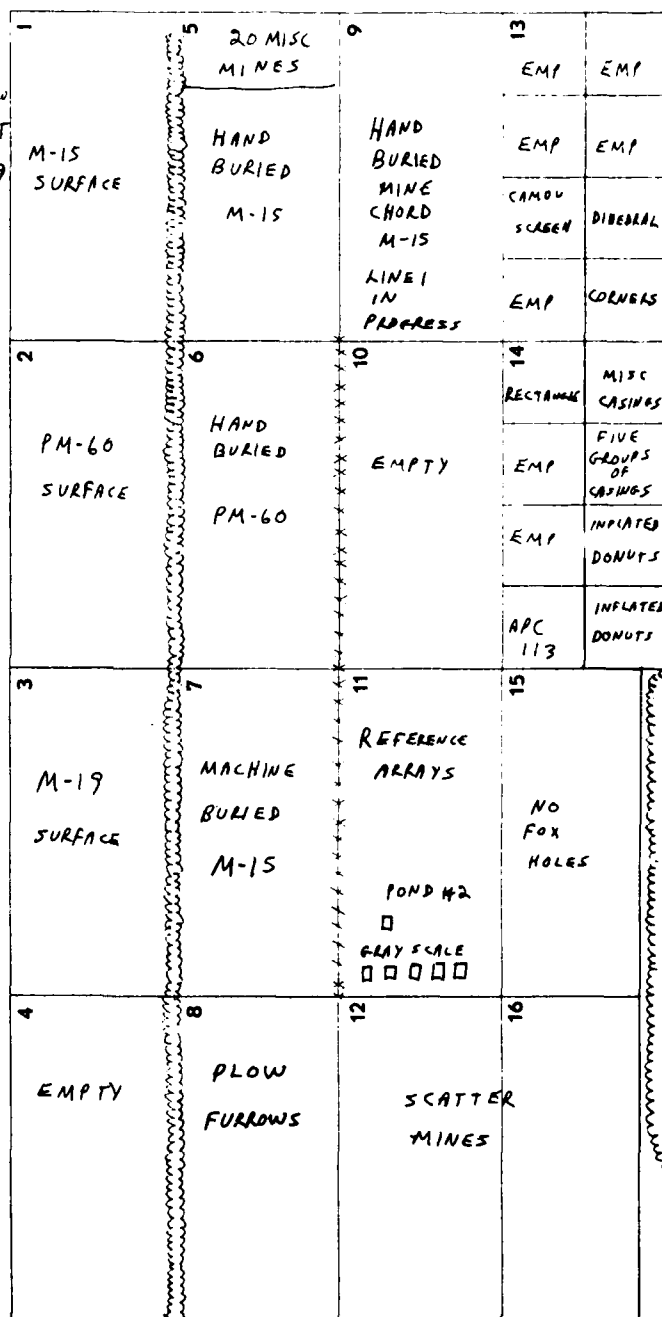


FIGURE 6-3. MINEFIELD LAYOUT, JULY 19, 1979, 4:10 PM



FLIGHT IDENTIFICATION
MOHAWK AIRCRAFT
 DATE JULY 19, 1979
 TIME 9:10 PM
 AIR TEMP 67°F
 PRECIPITATION
 LAST 24 HR 0
 REL HUM 70%
 WIND
 SPEED 0
 DIRECTION
 CLOUD COVER PARTLY

FOREST AREA



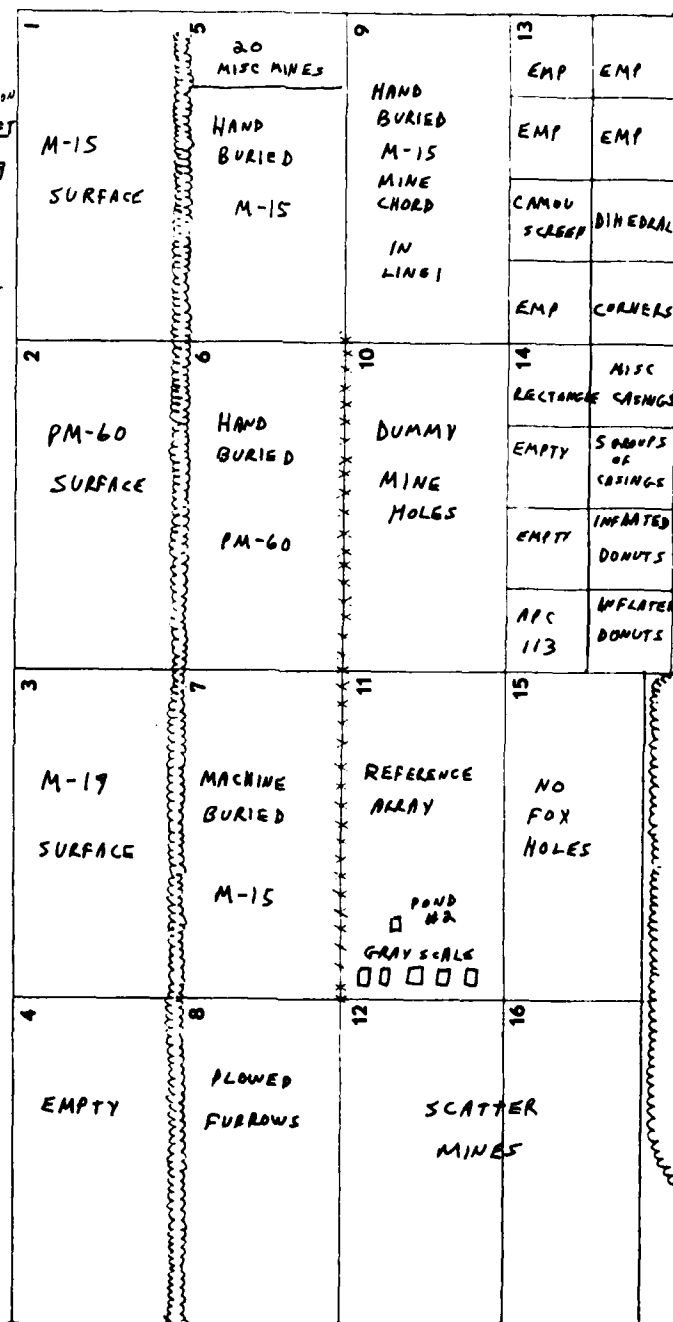
FOREST AREA

FIGURE 6-4. MINEFIELD LAYOUT, JULY 19, 1979, 9:10 PM

C

FLIGHT IDENTIFICATION
MOHAWK AIRCRAFT
 DATE JULY 29 79
 TIME 10:00 AM
 AIR TEMP 66°F
 PRECIPITATION
 LAST 24 HR 0
 REL HUM 72
 WIND
 SPEED 0
 DIRECTION
 CLOUD COVER CLEAR

FOREST AREA



FOREST AREA

FIGURE 6-5. MINEFIELD LAYOUT, JULY 20, 1979, 10:00 AM

FLIGHT IDENTIFICATION
NOHAWK AIRCRAFT
 DATE JULY 20, 1979
 TIME 12:30 PM
 AIR TEMP 82°F
 PRECIPITATION 0
 LAST 24 HR 0
 REL HUM 40%
 WIND 0
 SPEED 0
 DIRECTION 0
 CLOUD COVER CLEAR

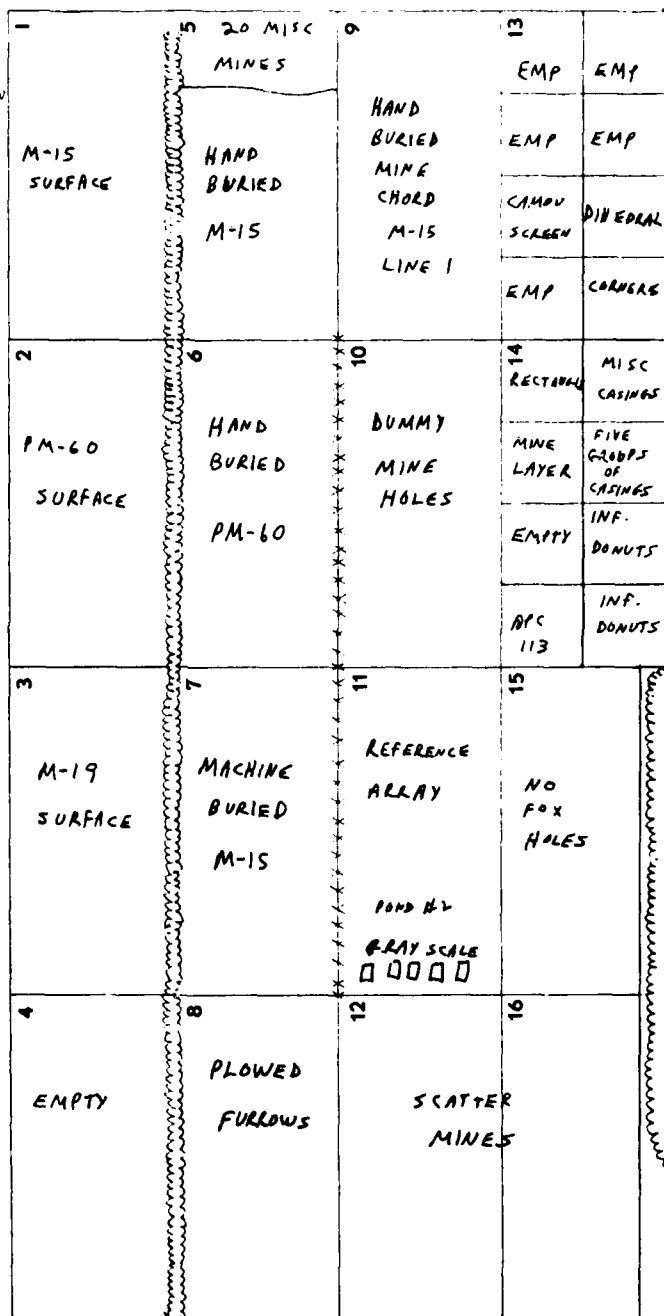


FIGURE 6-6. MINEFIELD LAYOUT, JULY 20, 1979, 12:30 PM

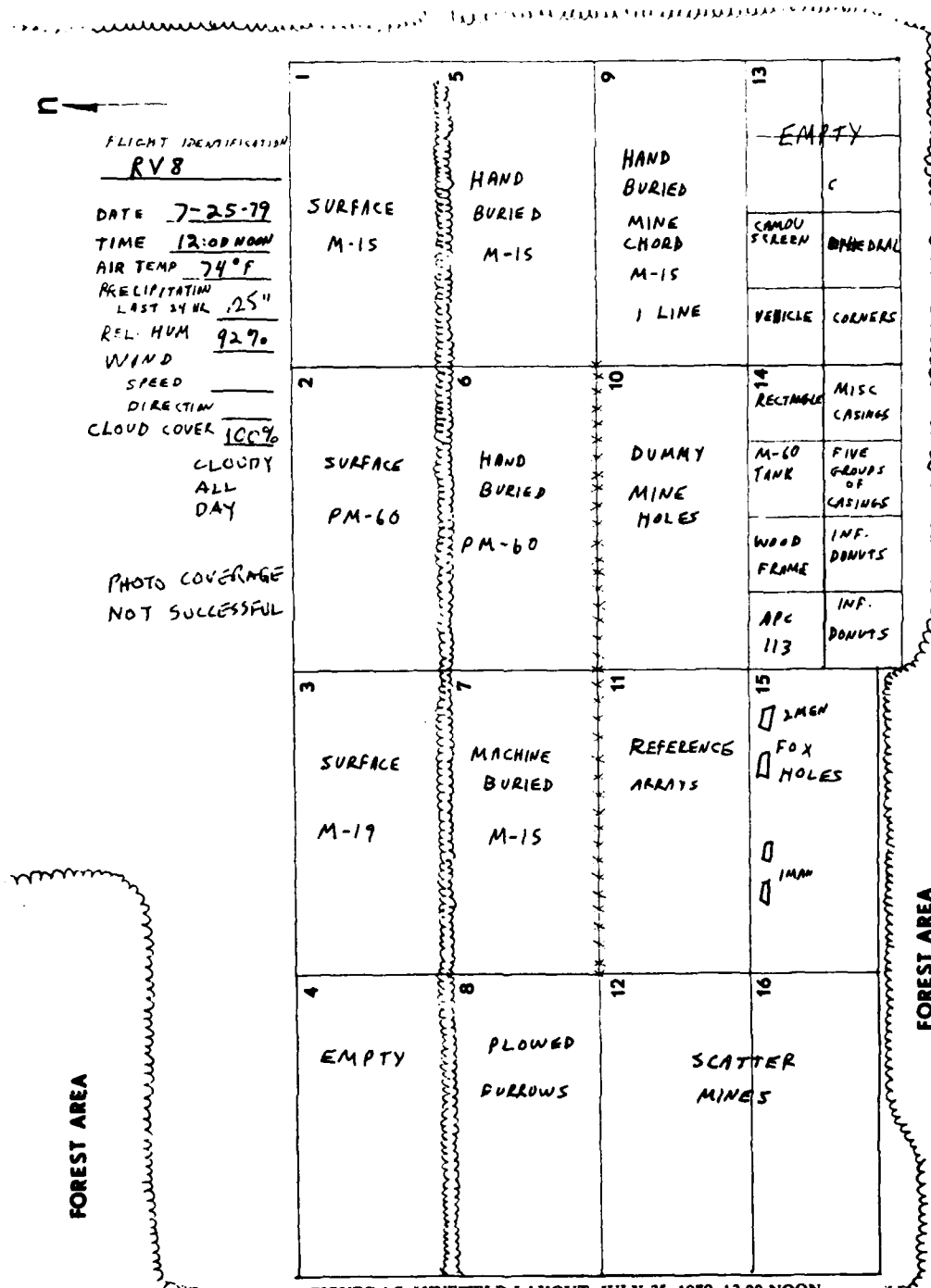


FIGURE 6-7. MINEFIELD LAYOUT, JULY 25, 1979, 12:00 NOON

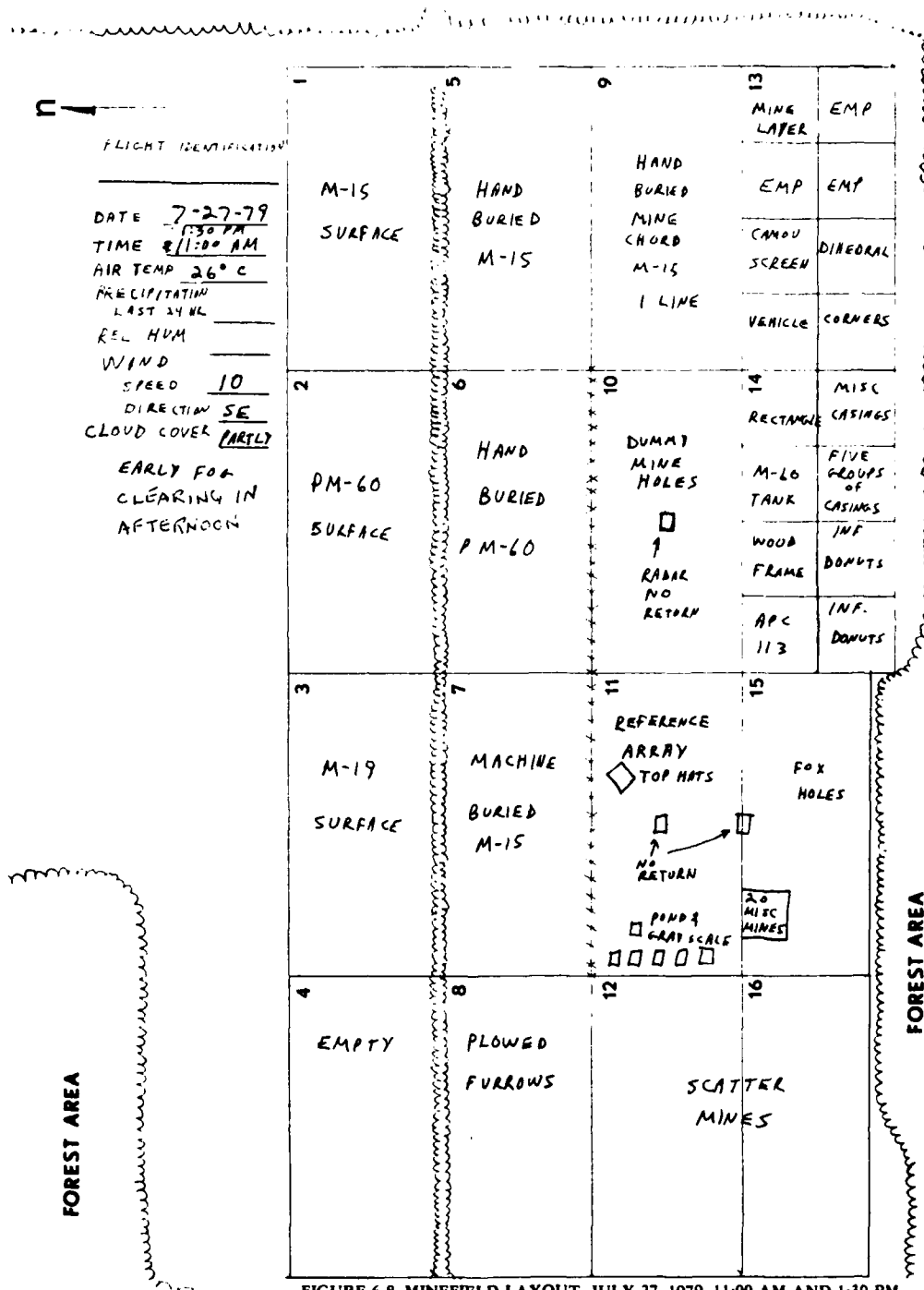


FIGURE 6-8. MINEFIELD LAYOUT, JULY 27, 1979, 11:00 AM AND 1:30 PM

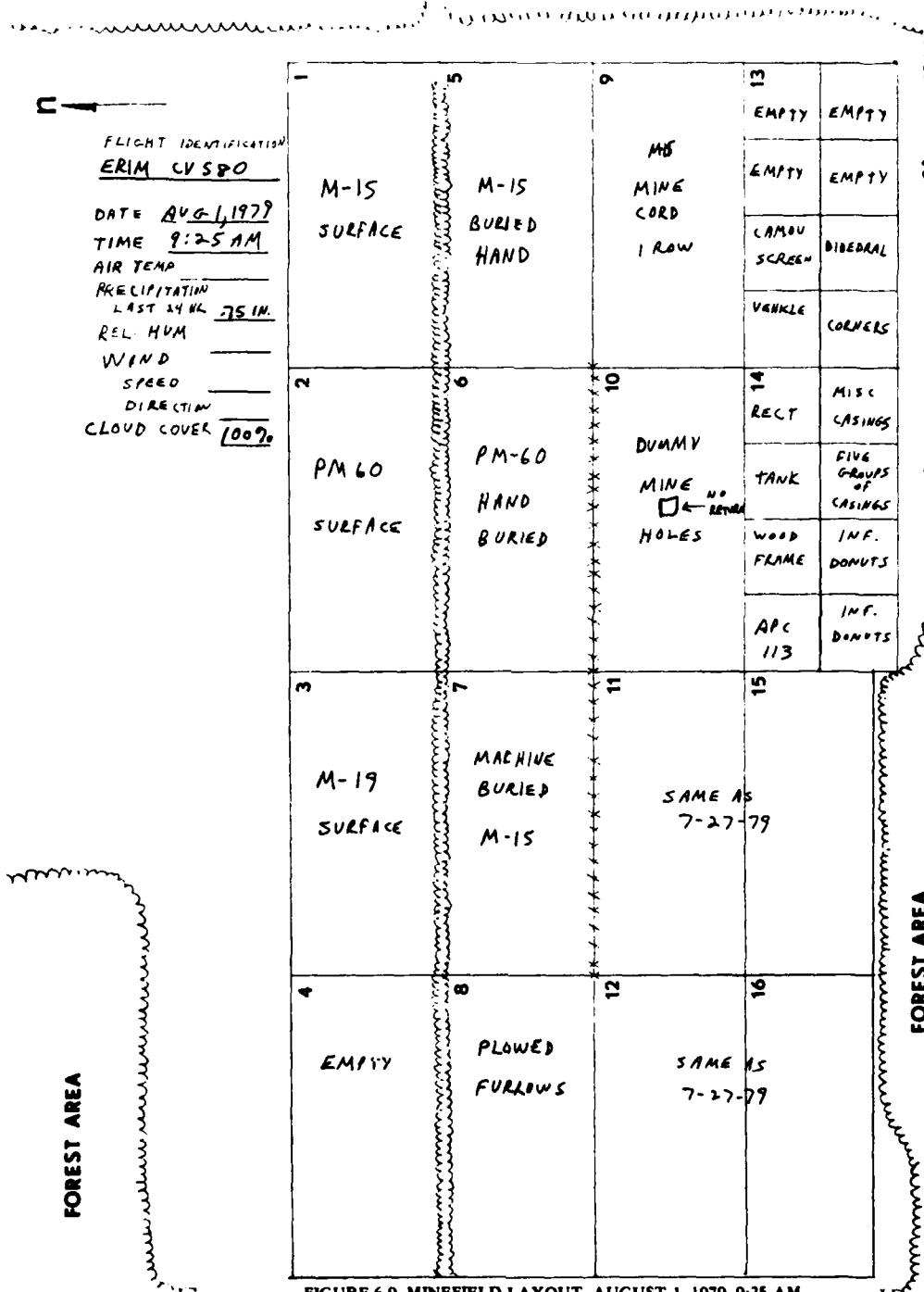


FIGURE 6-9. MINEFIELD LAYOUT, AUGUST 1, 1979, 9:25 AM

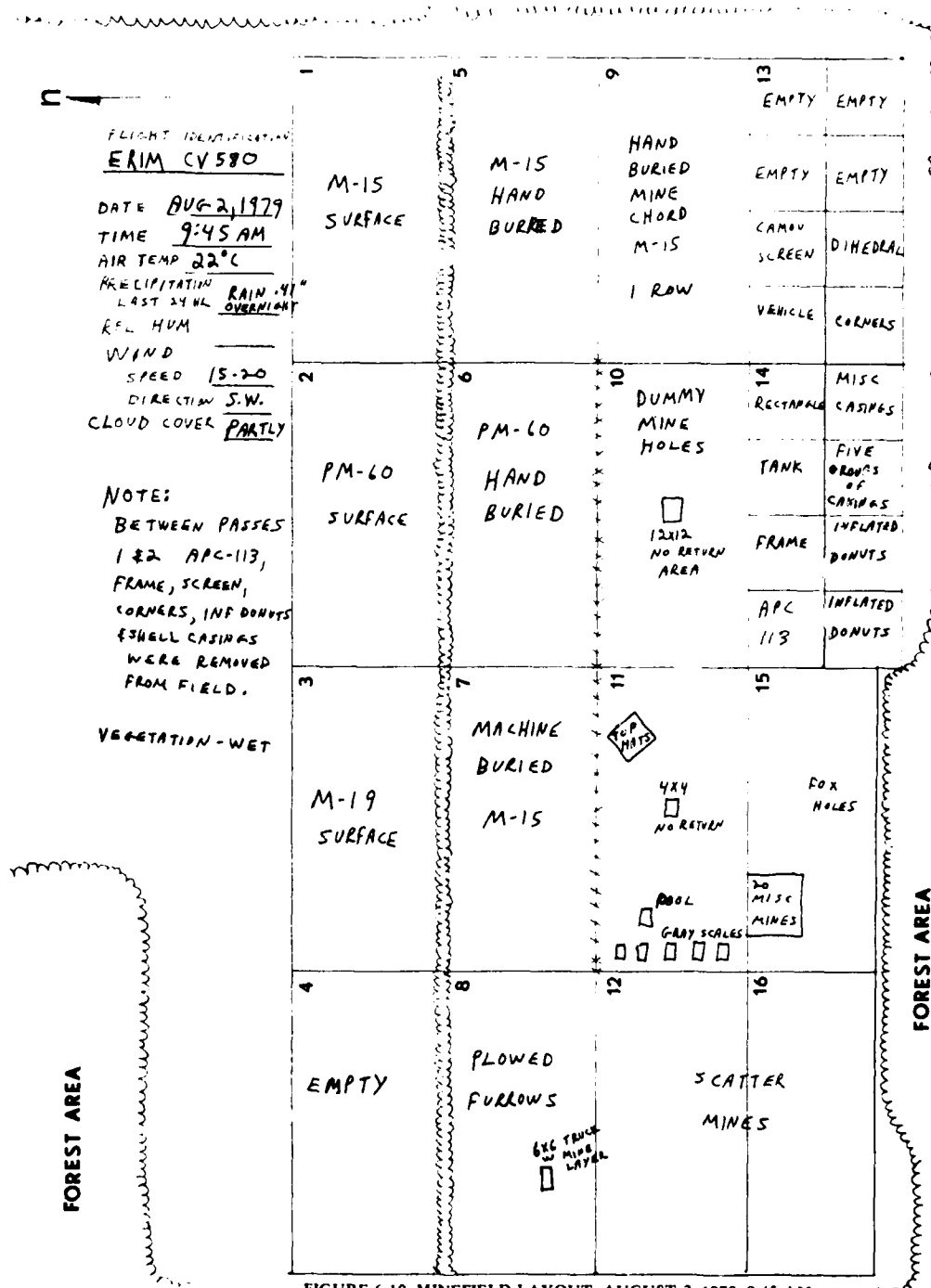


FIGURE 6-10. MINEFIELD LAYOUT, AUGUST 2, 1979, 9:45 AM

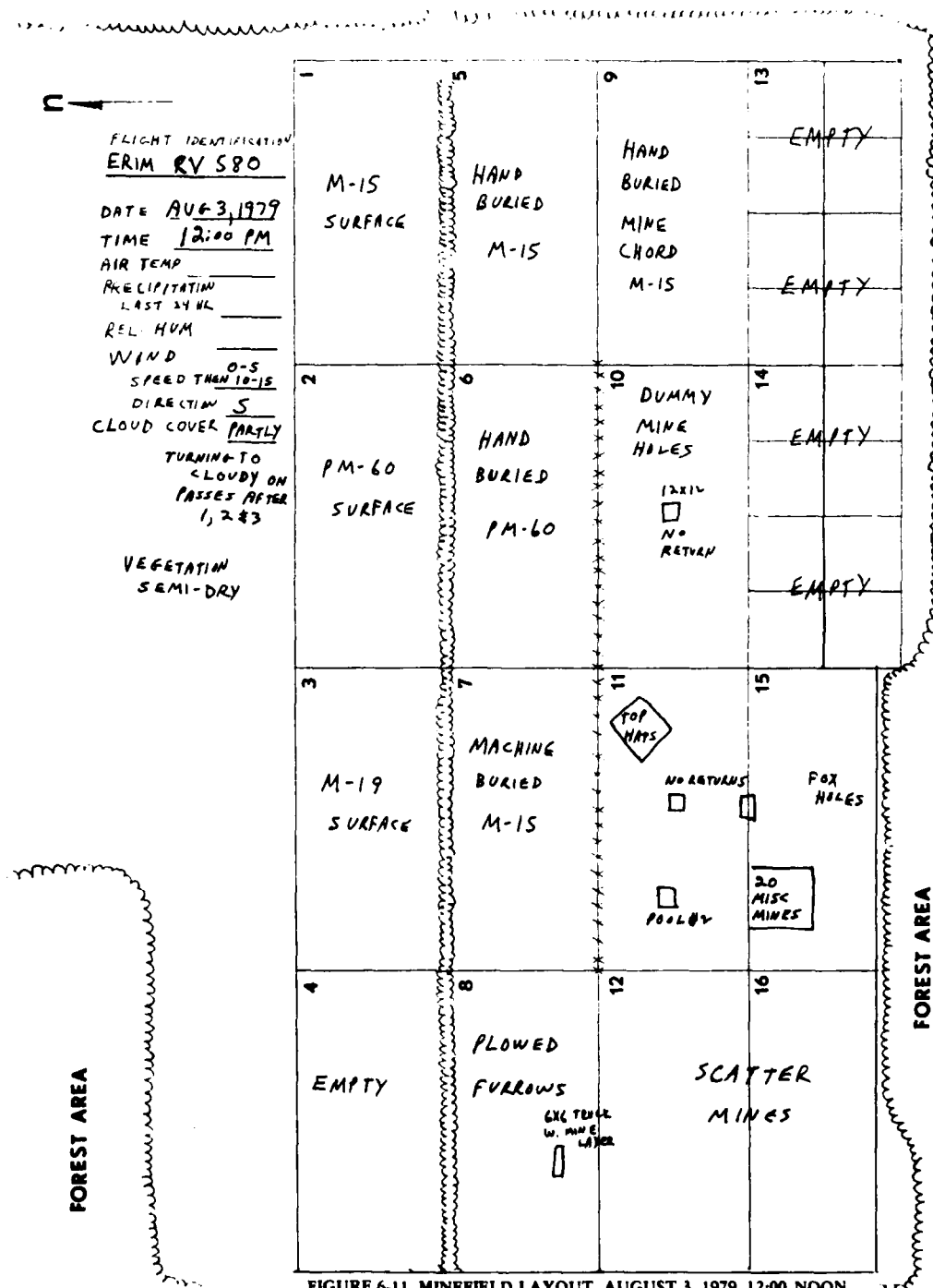


FIGURE 6-11. MINEFIELD LAYOUT, AUGUST 3, 1979, 12:00 NOON

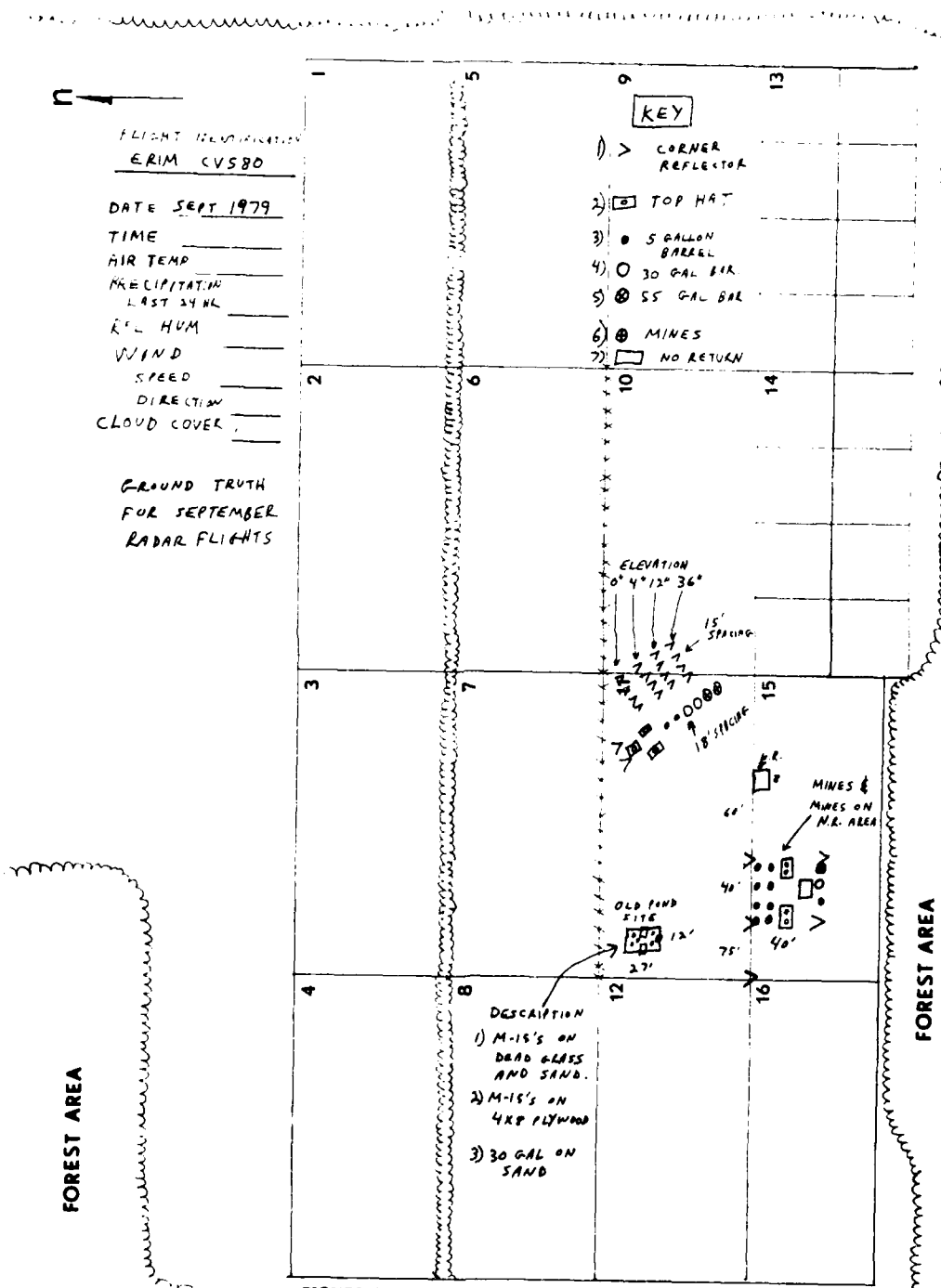


FIGURE 6-12. MINEFIELD LAYOUT, SEPTEMBER, 1970

TABLE 6-1
GROUND TRUTH TEMPERATURES, °C, FOR OV-1D (MOHAWK) FLIGHT
ANN ARBOR TEST SITE, 19 JULY 1979, 11:00 AM

		TEST SAMPLES			
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
1)	Unpainted M-15's Element 5	43°	40°	41°	44°
2)	PM-60's Element 5	51°	50°	50°	53°
3)	Scattermines Element 5	36°	36°	24°*	37°
4)	Painted M-15's Element 5	40°	41°	41°	41°
5)	M-19's Element 5	38°	38°	38°	44°
6)	Water Pond Element 11	20°	20°	21°	
7)	Air Temp. Element 6				
8)	Heat Exchange Panels Element 11	White Gray Black	22° 32° 54°		
9)	Gray Scale Panels	White 1 38° 38°	2 45° 45°	3 48° 47°	4 50° 52°
					Dark 5 50° 52°
10)	Hand Buried M-15's	35°	32°	35°	
11)	Hand Buried PM-60's	48°	46°	49°	
12)	Back Ground High Low	20° 23°			
	Machine Buried M-15's	32°	38°		

*Unpainted and Shiny

TABLE 6-2.
GROUND TRUTH TEMPERATURES, °C, FOR OV-1D (MOHAWK) FLIGHT
ANN ARBOR TEST SITE, 19 JULY 1979, 4:00 PM AND 9:15 PM

		TEST SAMPLES			
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
1)	Unpainted M-15's Element 5	52°/18°	52°/18°	52°/20°	50°/18°
2)	PM-60's Element 5	60°/17°	58°/16°	59°/17°	58°/17°
3)	Scatter Mines Element 5	45°/18°	46°/20°	20°/17°	*41°/19°
4)	Painted M-15's Element 5	50°/20°	50°/20°	51°/18°	52°/20°
5)	M-19's Element 5	48°/16°	50°/16°	48°/16°	49°/16°
6)	Water Pond Element 11	37°/25°	30°/22°	31°/21°	36°/20° 32°/22°
7)	Air Temp Element 6				
8)	Heat Exchange Panels	White			30°/15°
		Gray			55°/14°
		Black			56°/16°
9)	Gray Scale Panels Element 11	White			Dark
		1	2	3	4 5
		40°/10°	48°/11°	52°/10°	54°/12° 58°/12°
		40°/10°	48°/10°	50°/10°	56°/12° 58°/12°
10)	Hand Buried M-15's	54°/16°	53°/16°	52°/16°	
11)	Hand Buried PM-60's	41°/15°	61°/16°	63°/15°	
12)	BackGround	High		23°/14°	
		Low		30°/14°	
13)	Machine Buried M-15's	None			

*Unpainted and Shiny

TABLE 6-3
GROUND TRUTH TEMPERATURES, °C, FOR OV-1D (MOHAWK) FLIGHT
ANN ARBOR TEST SITE, 20 JULY 1979, 10:00 AM and 12:30 PM

		TEST SAMPLES			
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
1)	Unpainted M-15's Element 5	22°/58°	30°/56°	34°/54°	34°/48°
2)	PM-60's Element 5	39°/69°	38°/66°	38°/64°	38°/66°
3)	Scatter Mines Element 5	22°/44°	21°/48°	8°/20°*	20°/40°
4)	Painted M-15's Element 5	33°/54°	33°/56°	32°/55°	34°/56°
5)	M-19's Element 5	28°/60°	25°/60°	27°/58°	38°/62°
6)	Water Pond Element 11	18°/26°	18°/30°	20°/32°	19°/28°
7)	Air Temp. Element 6				
8)	Heat Exchange Panels	White Gray Black		24°/36° 37°/60° 42°/66°	
9)	Gray Scale Panels	White 1	2	3	4
		24°/44°	28°/56°	31°/59°	32°/63°
10)	Hand Buried M-15's	26°/52°	26°/44°	22°/48°	
11)	Hand Buried PM-60's	30°/44°	32°/60°	24°/68°	
					Dark 5 30°/65°

*Unpainted and Shiny

TABLE 6-4.
GROUND TRUTH TEMPERATURES, °C, FOR RF-4C FLIGHT,
ANN ARBOR TEST SITE, 1 AUGUST 1979, 11:00 AM

		TEST SAMPLES			
		1	2	3	4
1)	Unpainted M-15's Element 15	30°	29°	30°	30°
2)	PM-60's Element 15	34°	32°	32°	34°
3)	Scatter Mines Element 15	22°	26°	28°	28°
4)	Painted M-15's Element 15	29°	29°	30°	29°
5)	M-19's Element 15	32°	30°	30°	31°
6)	Water Pond Element 11	20°	20°	20°	20°
7)	Air Temp Element 6	25°	24°		
8)	Heat Exchange Panels Element 11	White Gray Black		23° 34° 34°	
9)	Gray Scale Panels	White 1 24° 25°	2 28° 29°	3 30° 30°	4 32° 32°
					Dark 5 34° 34°
10)	Hand Buried M-15's Element 5	20°	18°	24°	
11)	Hand Buried PM-60 Element 6	26°	26°	28°	
12)	Background	High Low	18° 22°		
13)	Machine Buried M-15's	26°	26°	28°	



TABLE 6-5
SCHEDULE OF MINEFIELD TEST COMPONENTS

<u>Element</u>	<u>Contents</u>	<u>Date Finished</u>
1	Painted M-15 surface Mines spaced at 25' intervals	07/18/79
2	PM-60 surface mines spaced at 25' intervals	07/18/79
3	M-19 surface mines spaced at 25' intervals	07/18/79
4	Empty	
5	M-15 hand buried mines spaced at 17' intervals	07/05/79
6	PM-60 hand buried mines spaced at 17' intervals	07/06/79
7	M-15 minelayer buried mines spaced at assorted intervals	07/08/79
8	A) Open and closed mine furrows 2 of each alternating rows B) Short open furrow	07/08/79
9	A) M-15 hand buried mine in mine cord pattern in SE corner only * B) 20 misc surface mines C) Large radar corner	07/19/79 08/03/79
10	A) Dummy mine holes spaced at 25' intervals B) No return areas (12' x 12')	07/26/79
11	Tophats No return areas (4' x 4') ** Pool #2 (12' x 12') Canvas panels	08/01/79 07/26/79 07/19/79 Set out for every flight

* The 20 misc surface mines were moved to element 15 on 07/26/79

** Pool #1 was built on 07/18/79 then torn down and replaced with
pool #2 on 07/19/79

TABLE 6-5. (Continued)

<u>Element</u>	<u>Contents</u>	<u>Date Finished</u>
12	Scatterable mines spaced in assorted patterns and intervals	07/19/79
13	Screen Radar Corners US Army vehicle Aluminim angles	07/19 & 20/79
14	Rectangle Shell casing (misc) INF donuts Frame Tank APC 113	07/19 & 20/79
15	20 misc mines No return area (8' x 8') Four foxholes	07/26/79 07/26/79 07/23/79
16	Scatterable mines	07/19/79
Misc	Fence posts Radar corners on ground by fence posts Radar corners on fence posts Barbed wire fence	07/11/79 07/26/79 08/03/79 07/10/79

APPENDIX A
ASSESSMENT OF MINE CHARACTERISTICS

This appendix contains four memos discussing measurements and analyses of mines carried out to test the equivalency of the simulated PM-60 to the real PM-60 and the M-15 U.S. antitank mine to the TM-46 Russian equivalent. Conclusions reached from these measurements and analyses are summarized below.

1. Memo, E. L. Johansen to H. McKenney, 23 May 1979, "X-Band RCS Measurements on New Simulated PM-60".

Radar cross-section measurements were made of a new simulated PM-60 and a real PM-60 filled with wax. The measurements indicate that the simulated PM-60 has the same mean cross section as the real PM-60 and is therefore a good replacement for it in the mine arrays for measurements with imaging radars operating in X-band.

2. Memo AD-DB-331, D. Bornemeier to H. McKenney, 22 May 1979, "Simulated PM-60's".

Inspection of the simulated PM-60 indicated that the electro-optical response should be similar to the real PM-60 if two coats of paint are applied to the simulated PM-60. For thermal simulation, the similarity is questionable since the present fill of the simulated PM-60 is only about 11 lb. compared to 25 lb. for the real mine.

3. Memo AD-DB-509, D. Bornemeier to H. McKenney, 22 October 1979, "Thermal Match of PM-60's".

Measurements were carried out to estimate the degree to which the simulated PM-60 mines simulate the thermal response of the real PM-60's. Since a real PM-60 was not available, for comparison, it was represented by filling an empty dummy casing with toluene to simulate the thermal characteristics of TNT and a thin air bubble

was incorporated at the top, similar to that contained in the real mine.

The toluene-filled PM-60 and wax-filled simulated PM-60 were then placed on open grass and observed frequently with an 8 to 14 μm radiometer during both cloudy and sunny weather. The observed temperature difference did not exceed 3°C, and was mostly less than 1°C. It is concluded that the simulated mines are adequate thermal representations of the real PM-60's.

4. Memo SP-79-692, D. Bornemeier to H. McKenney, 13 December 1979, "Results - TM-46 Measurements".

Radiometric measurements at 8 to 14 μm were made during December on a real TM-46 anti-tank mine, a simulated PM-60, and two inert M-15s painted to match the TM-46. The M-15s were found to give a good thermal approximation to the real TM-46. However, the TM-46 has noticeably less thermal inertia than the M-15.



23 May 1979

MEMORANDUM TO: H. McKenney
FROM: E.L. Johansen
SUBJECT: X-band RCS Measurements on New Simulated PM-60
Project 138331

We recently received two new simulated PM-60 mines from the manufacturer. With the rotary platform instrumentation, we made cross-section measurements of the new simulated PM-60 and of a real PM-60 filled with wax. The center frequency of the measurements was 10 GHz and the depression angle 3° . The polarizations were vertical and horizontal.

For the measurements the returns of the simulated PM-60 and the real PM-60 filled with wax were recorded as the platform rotated. For both polarizations the mean cross section of the simulated PM-60 differed from the cross section of the real PM-60 by less than one or two dB. The fine grain structures of the two mines were somewhat different; the cross section of the real PM-60 varied more rapidly but this small difference is not significant.

The cross section measurements indicate that the new simulated PM-60 has the same mean cross section as the real PM-60. The new simulated PM-60 will, therefore, be a good replacement for real PM-60's in the mine arrays for measurements with imaging radars operating in X-band.

ELJ/vo



ANALYSIS DEPARTMENT

22 May 1979
AD-DB-331

To: H. McKenney
From: D. Bornemeier >
Subject: Simulated PM-60's

I have inspected the prototype PM-60's (two) received from the manufacturer last week! They appear to be adequate as regards the expected similarity of EO responses from them as compared to real PM-60, with the following reservations: (1) At least two coats of paint should be applied according to Lafferman (MERADCOM), and (2) the mines with the present fill are only about 11 lb compared to 25 lb for the real mine.

This later point is not important for active EO simulation, but may be for thermal (passive IR). There is however no requirement that the thermal and radar properties be simulated simultaneously. A quick measurement using a hand-held radiometer to compare the 8-14 μ response of a real PM-60 and a simulated PM-60 would resolve this question.

cc: J. Beard



ANALYSIS DEPARTMENT

22 October 1979
AD-DB-509

To: H. McKenney
From: D. Bornemeier
Subject: Thermal Match of PM-60's

Measurements have been carried out to estimate the degree to which the existing PM-60 surrogate mines represent (from a thermal response standpoint) real PM-60's. A real PM-60 with TNT charge is not available for comparison; hence, some compromise in the comparison was necessary. Outlined below is the procedure used to estimate thermal match and the results.

The present set of mines were made to simulate radar responses of the real mines. As such, they were filled with S 446 wax (Shamrock Chemical Company product) which had the proper dielectric properties. A thin, 3/8 to 1/4 inch thick, air bubble like the real mine was incorporated at the top (between the wax and the inside) in the dummies. Upon inquiry, Shamrock was unable to state the thermal conductivity or specific heat of the S 446 wax. Hence no direct theoretical comparison of the wax and TNT could be made. A search however revealed that toluene has thermal properties similar to TNT. It was therefore decided to simulate a real PM-60 by filling an empty dummy casing with toluene to simulate the thermal aspect of TNT and the air bubble.

To: H. McKenney
Page 2

22 October 1979
AD-DB-509

A dummy casing was coated inside with two coats of polane (TM), a material resistant to toluene (the Norel plastic of the case is dissolveable in toluene) and dry baked in a microwave oven. The mine was then filled with toluene such that when the mine was flat (bottom down) a bubble of the same shape and size as those in the wax versions was formed.

The mines, wax filled and toluene filled, were then placed on an open grass terrain and observed frequently with an 8-14 μ m Barnes PRT-5 radiometer. Over a period of five days, including cloudy and sunny October days in Ann Arbor, the observed equivalent temperature difference did not exceed 3°C at any time. The differences were for the most part a degree or less. There were no especially sharp changes in the thermal driving functions during this time; hence, the fast transient thermal response which might occur on a hot July afternoon followed by a heavy cold rain were not tested. However, it appears that for practical purposes the present mines are adequate thermal representations of real PM-60's for the purposes of the IR detection studies.



13 December 1979

SP-79-692

MEMORANDUM TO: H. McKenney
FROM: D. Bornemeier *DOB*
SUBJECT: Results - TM46 Measurements

During the week of 3-7 December, radiometric measurements were made on a real TM46 anti-tank mine, AMERADCOM PM-60 surrogate and 2 inert M-15s which were painted with US olive drab to match the TM46. The purpose of the measurements was to compare the thermal response of the surrogate mines with that of a real mine under more or less nominal environmental driving functions.

Fortunately two good consecutive days of thermal data were acquired. The weather was clear and sunny and on the mild side for December at MERADCOM (Ft. Belvoir, VA). Measurements were carried out inside a double "fenced-in" area at the engineering proving grounds at MERADCOM. The mines were laid out on a short grassy terrain and a PRT-5 portable radiometer measuring in the 8-14 μ m band was used to gather data. The summarized raw-data is given in the accompanying tables. The temperature-vs-time curves corresponding to the real TM-46; the M-15s and the immediately adjacent terrain are shown in the attached figure. The M-15 data is the average of the two M-15s.

As can be seen from the curves, the M-15s do give a good approximation to the real TM46 with respect to thermal response. There is, however, a noticeable difference. The TM46 has less thermal inertia, i.e., the real mine warms up faster and cools down faster than the sand filled M-15s. Any data (passive IR imagery) taken with the surrogate mines will probably represent quite closely what could be expected if real mines were used. It is possible that a wax fill like that used for the PM-60s would provide an even better match; however, it is not recommended that this later investigation be carried out.

DB/vo

cc: R. Nalepka
Y. Morita



PRT-5 READING ON LAND MINES

Fort Belvoir, VA
12/03/79

<u>Time</u>	<u>M15</u>	<u>TM46</u>	<u>M15</u>	<u>PM60</u>	<u>Air Temp</u>	<u>Ground</u>	<u>Comments</u>
12:00 pm	18°C	20°C	18°C	21°C	43°F	19°C	Sunny
1:00	22	24	21	26	50	21	Sunny
2:00	18	20	18	22	50	20	Sunny
3:00	14	10	14	14	48	16	Sunny
4:00	6	4	6	6	45	8	Sunny
5:00	-2	-4	-2	-8	35	-6	Sunset
6:00	-6	-8	-6	-10	35	-8	Clear
7:00	-10	-12	-10	-12	32	-8	
8:00	-50	-50	-50	-50	25	-50	Mines & grass wet/ bad battery -
11:00	-14	-17	-14	-16	32	-16	Cold, damp
3:00 am	-14	-17	-14	-16	32	-16	Cloudy
6:00	-10	-10	-10	-8	32	-8	Frosty
7:00	2	2	2	4	32	2	Sunrise, frosty
8:00	4	4	4	4	32	2	Frosty
9:00	4	4	4	4	32	4	
10:00	2	4	2	4	40	4	Partly cloudy
11:00	10	8	10	12	45	6	Sunny
12:00 pm	14	16	14	16	50	10	Sunny

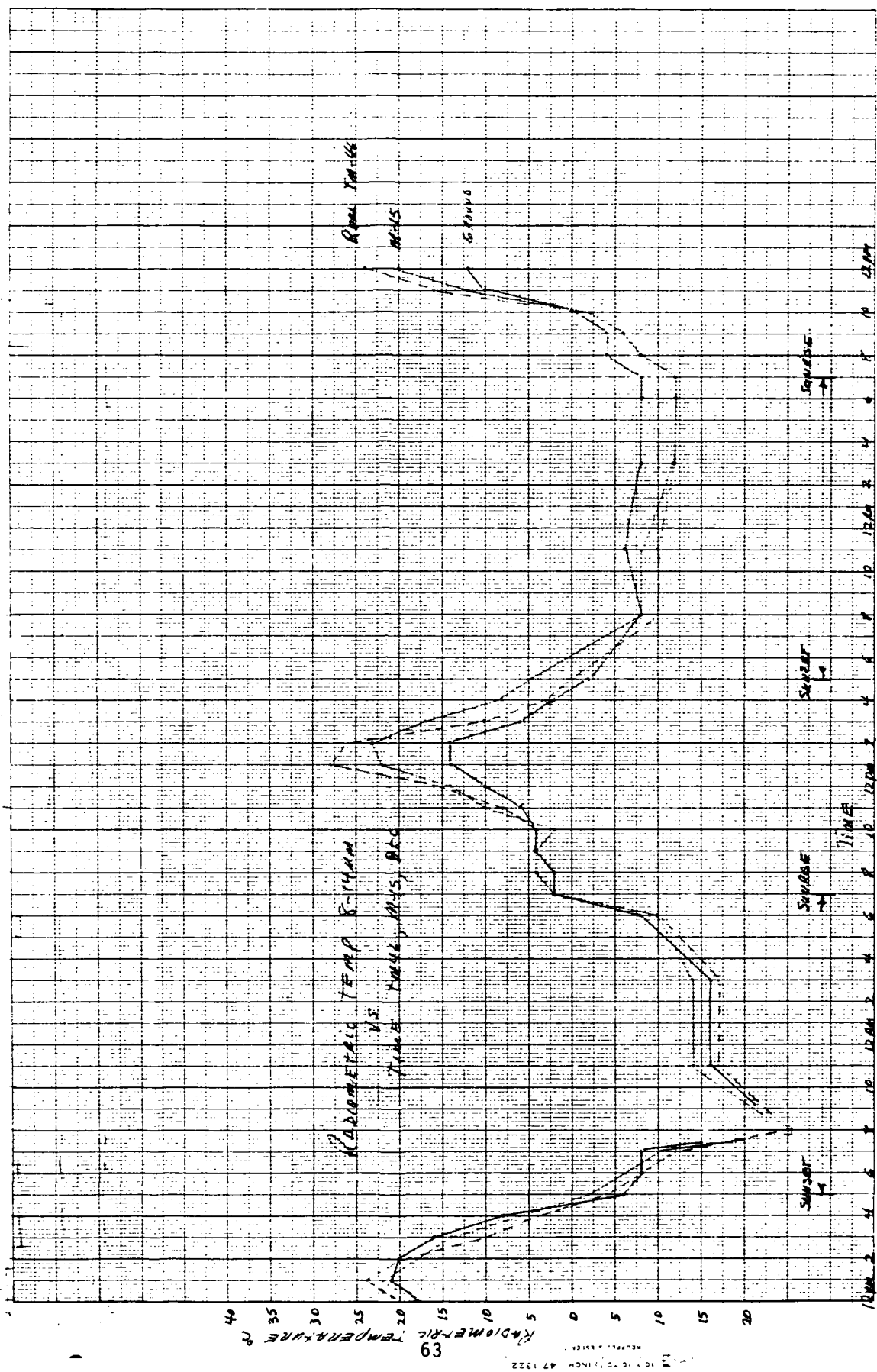


PRT-5 READING ON LAND MINES

Fort Belvoir, VA
12/04/79

<u>Time</u>	<u>M15</u>	<u>TN46</u>	<u>M15</u>	<u>PM60</u>	<u>Air Temp</u>	<u>Ground</u>	<u>Comments</u>
12:00 pm	14°C	16°C	14°C	16°C	50°F	10°C	Sunny/clear
1:00	22	28	22	26	52	14	Sunny/clear
2:00	22	26	24	26	52	14	Sunny/clear
3:00	14	10	12	10	48	6	Sunny/clear
4:00	8	8	8	6	45	2	Sunny/clear
5:00	4	0	4	2	42	-2	Sunset
8:00	-8	-10	-8	-12	29	-8	Clear
11:00	-8	-10	-8	-8	28	-6	Clear
3:00 am	-12	-12	-12	-12	20	-8	Clear
6:00	-12	-12	-12	-12	20	-8	Frosted
7:00	-12	-12	-12	-10	20	-8	Frosted
8:00	-8	-8	-8	-8	25	-4	Frosted
9:00	-6	-6	-8	-6	32	-4	Sunny/clear
10:00	-2	-2	-2	-2	37	0	Sunny/clear
11:00	12	16	12	18	48	10	Sunny/clear
12:00 pm	20	24	20	24	50	12	Sunny/clear

*10 mph wind out of southwest



1/4" x 10" x 10" 47 1922

APPENDIX B

METEOROLOGICAL DATA

Appendix B contains a record of weather observations in the Ann Arbor area during the flight test period, as provided by the University of Michigan Weather Station located in Ann Arbor.

STATION (Name, Location, Elevation)		MONTH		COUNTY		STATE	
ANN ARBOR, MICHIGAN		AUG 1979		WASHTENAW		MI	
TYPE OF RIVER GAGE		TEMPERATURE PRECIPITATION		STANDARD TIME IN USE		NORMAL POOL STAGE	
ANN ARBOR, MICHIGAN		1700 1700		EDT		1700	
ELEVATION OF RIVER		PRECIPITATION		STANDARD TIME IN USE		NORMAL POOL STAGE	
1700		1700		EDT		1700	
DATE	TIME	COND.	TEMP.	PRECIP.	WIND	WAVE	STAGE
1	83	65	70	0.03	0.03	0.03	0.03
2	78	63	78	0.01	0.01	0.01	0.01
3	79	67	73	0.01	0.01	0.01	0.01
4	85	63	75	0.01	0.01	0.01	0.01
5	81	65	80	0.03	0.03	0.03	0.03
6	80	61	77	0.01	0.01	0.01	0.01
7	91	60	91	0.01	0.01	0.01	0.01
8	91	64	80	0.01	0.01	0.01	0.01
9	80	60	76	0.01	0.01	0.01	0.01
10	81	64	77	0.01	0.01	0.01	0.01
11	77	57	68	0.01	0.01	0.01	0.01
12	74	47	73	0.01	0.01	0.01	0.01
13	73	45	65	0.01	0.01	0.01	0.01
14	68	59	64	0.08	0.08	0.08	0.08
15	70	48	69	0.01	0.01	0.01	0.01
16	73	45	72	0.01	0.01	0.01	0.01
17	72	45	57	0.01	0.01	0.01	0.01
18	71	55	71	0.01	0.01	0.01	0.01
19	75	63	73	0.01	0.01	0.01	0.01
20	73	60	60	0.01	0.01	0.01	0.01
21	78	57	70	0.05	0.05	0.05	0.05
22	77	58	70	0.01	0.01	0.01	0.01
23	76	64	66	0.01	0.01	0.01	0.01
24	78	65	76	0.01	0.01	0.01	0.01
25	76	53	71	0.01	0.01	0.01	0.01
26	75	57	71	0.01	0.01	0.01	0.01
27	71	58	69	0.01	0.01	0.01	0.01
28	76	63	75	0.01	0.01	0.01	0.01
29	77	65	78	0.01	0.01	0.01	0.01
30	85	63	84	0.01	0.01	0.01	0.01
31	84	60	81	0.01	0.01	0.01	0.01
SUB	2412	1833					
CHECK BAR (If not checked) NORMAL CEILING							
REMARKS: IF MORE SPACE IS NEEDED, USE ADDITIONAL FORM							
1. max 76° 18. max 58° 2. max 79 20. max 61, 61.57 3. max 85 23. max 75 4. max 76 24. max 67 5. max 61 25. max 81 6. max 71, 61.57 7. max 72 8. max 60 9. max 60							
OBSERVER DENNIS F. KANLARIUM							

20-0230-0

ANN ARBOR, MI WSFO

STATION INDEX NO.

SUPERVISING OFFICE

TABLE B-1

SUPPLEMENTAL REMARKS

KEY FOR SUPPLEMENTAL REMARKS

L = Drizzle
RW = Rain Shower
R = Rain
TRW = Thunderstorm
'+' = Heavy
' ' = moderate
'-' = light
'XX' = severe

CLOUD EXTENT

○ = clear 0 - 0.1
① = scattered 0.1 - 0.5
② = broken 0.5 - 0.9
⊕ = overcast 0.9 - 1.0

RW - B0310E2030 = Light Rain Showers Began 3:10 AM Ended 8:30 PM

F06 Vis = 1-1/2 mi 02 = 1-1/2 vis fog at 2:00 AM

SUPPLEMENTARY REMARKS, ANN ARBOR, MICH, JULY 1979

ALL TIMES ARE EDT

1. MAX = 62, L = 80500, RW = 80500E1015, OCH L = 8400E1300, RW = 81600E1015B1645E1715, Fog Vis = 5mi. 01-05, 3mi. 05, 2mi. 06-08, 3mi. 09-10, 4mi. 11, 3mi. 12, 4mi. 13-15, 3-4mi. 11-20, 5-6mi. 21-24, \oplus Sc 01-05, \oplus Sc 5-06-24
2. MAX = 74, RW = 80045E0115, L = 840430E0900, Gnd Fog APPR 2000, \oplus Sc 01-03, \oplus Sc 04-04, \oplus Cu 04-05, \oplus Sc 06-08
 \oplus Sc 09, \oplus Sc 10-15, \oplus Sc 16, \oplus Sc 04-17, \oplus Sc 18, \oplus Cu 19-23, O24 Haze Vis = 5mi 09
3. 001-06, \oplus Ac 07-09, \oplus Ac 10-11, \oplus Ac 12, \oplus Cu 04-13, \oplus Cu 04-14-15, \oplus Cu 04-16-17, \oplus Ac 18-19, \oplus Ac 20, \oplus Ac 21-24
4. TRW = 80230E0300, RW = 80200E0645, \oplus Ac 01-02, \oplus Sc 03-04, \oplus Sc 04-09, \oplus Cu 10, 01-12, \oplus Ac 13, \oplus Cu 14, \oplus Cu 15-19, \oplus Cu 20-23, O24
5. MAX = 70, 001-11, \oplus Cu 12-17, \oplus Cu 04-18, O19-24
6. 001-03, \oplus Cu 04-05, 006-14, \oplus Cu 15-16, \oplus Cu 04-17, \oplus Sc 18-20, \oplus Sc 21, O22-24
7. 001-16, \oplus Sc 17-19, \oplus Sc 20-23, \oplus Sc 24 Haze Vis = 6mi. 19.
8. \oplus Cu 01, 002-05, \oplus Sc 06-07, \oplus Sc 08-09, \oplus Sc 10-15, \oplus Sc 16, \oplus Sc 17-19, \oplus Ac 04-20, \oplus Ac 04-21, \oplus Sc 22-23, \oplus Ac 24
Haze Vis = 6mi. 17-19, 4-5mi. 20-23, 3mi. 24
9. MAX = 73, RW = 80445E0630B0815E0930B1100E1215, RW = VRW = 81000E1100, TRW = 815E1400, \oplus Ac 01-04, \oplus Ac 05-06,
 \oplus Sc 07-12, \oplus Sc 13-14, \oplus Sc 15-17, \oplus Cu 18, \oplus Cu 19, \oplus Cu 20, \oplus Ac 21, \oplus Sc 22, O23-24, Fog Vis = 2 1/2mi. 07-08,
2mi. 09, 2 1/2mi. 10, 3mi. 11, 2mi. 12, 1mi. 13, 1 1/2mi. 14, 3mi. 15-16; Haze Vis = 5mi. 01-02, 6mi. 17, 5mi. 23 SEA = 4mi. 06, SW APPR = 50
10. 001-02, \oplus Cu 03-04, \oplus Sc 05-06, \oplus Sc 07-10, \oplus Cu 11, \oplus Cu 12-15, \oplus Cu 16, \oplus Cu 17-20, \oplus Ac 21-22, \oplus Sc 23,
 \oplus Sc 24; Fog & Haze Vis = 2mi. 04, 1 1/2mi. 05-06, 2mi. 07-08, 2 1/2mi. 09, 3mi. 10, 4mi. 11, 5mi. 12; Haze Vis = 5mi. 03,
5mi. 12-13, 6mi. 16, 4mi. 17-20, 5mi. 21, 4mi. 22, 3mi. 23-24
11. RW = 81210, RW = 81400E1115, TRW = 81630E1655, TRW = 81830E1700, TRW = 81900E1800, TRW = 82000E2030, Thunder until 2000;
 \oplus Sc 01-02, \oplus Sc 03-11, \oplus Ac 12-13, \oplus Sc 14-15, \oplus Sc 04-16, \oplus Sc 06-17-19, \oplus Sc 04-20-21, \oplus Ac 04-22, \oplus Ac 23, \oplus Ac 24, Fog/Haze Vis =
2-3mi. 01-05, 1 1/2mi. 06, 1 1/2mi. 07, 2-3mi. 10-11; Haze Vis = 3-4mi. 12-21; * TRW XX reported NONE of Ann Arbor; 6-8" of rain reported at
Warren, Troy, & Dearborn Rds, heavy damage to roads, bridges, tunnels because of rapid flooding; SE DB = T, SW = .01, DP = .05, Tilted Dr. = 1.91"
12. \oplus Ac 01-02, \oplus Ac 03, \oplus Ac 04-05, \oplus Sc 06, \oplus Cu 07, \oplus Sc 08-10, \oplus Sc 11-13, \oplus Cu 14, \oplus Sc 15-18
 \oplus Cu 04-17, \oplus Cu 20-22, \oplus Ac 23, \oplus Ac 24; Fog/Haze Vis = 2mi. 06, 1 1/2mi. 07, 2mi. 08, 3mi. 09; Haze Vis =
5mi. 01-02, 3mi. 03-07, 4-5mi. 10-19, 3-4mi. 20-24
13. MAX = 85, RW = 81730, L = 82000E2230, \oplus Sc 01, \oplus Sc 02, \oplus Sc 03, \oplus Sc 04, \oplus Sc 05-07, \oplus Sc 08-09
 \oplus Ac 10-12, \oplus Cu 14, \oplus Cu 15-17, \oplus Sc 18-19, \oplus Ac 20-21, \oplus Ac 22-24. Fog/Haze Vis = 3mi. 07-08,
2 1/2mi. 03, 2mi. 04-05, 1mi. 06-07, 2 1/2mi. 08-09, 2 1/2mi. 10-16; Haze Vis = 2 1/2mi. 17, 1 1/2mi. 18-19, 2mi. 20-23, 3mi. 24
SWA = .03, SE = T
14. MAX = 85, TRW = 81730E1750, RW = 81950E2015, (LIGHTNING E UNTIL 2000), \oplus Ac 01-02, \oplus Ac 03, \oplus Sc 04-05
 \oplus Ac 06-07, \oplus Sc 08-09, \oplus Ac 10-12, \oplus Cu 04-13, \oplus Ac 14, \oplus Ac 15-18, \oplus Cu 04-19, \oplus Cu 04-20, \oplus Cu 21,
 \oplus Cu 22, \oplus Cu 23, \oplus Cu 24; Fog/Haze = 1mi. 06-07, 4mi. 08, 1 1/2mi. 09-10; Haze Vis = 2-3mi. 01-05, 11-12; 4-6mi. 13-24.
SEA = .04, SWA = .17, DB = .25
15. \oplus Cu 01-02, \oplus Ac 03, 004-05, \oplus Sc 06, \oplus Cu 07-08, \oplus Sc 09, \oplus Sc 10, \oplus Cu 04-11-12, \oplus Sc 13-15,
 \oplus Cu 04-16-19, \oplus Cu 04-20, \oplus Cu 04-21, \oplus Sc 22, O23-24 Gnd Fog/Haze Vis = 3mi. 07, 4mi. 08; Haze Vis =
5mi. 01-02, 6mi. 09

SUPPLEMENTAL REMARKS, ANN ARBOR, MICH, JULY 1978

- 16 MAX=83, MIN=60, 001-05, 0106, 0107-08, 0109, 0110-14, 0115-16, 0117-19, 0120-22, 023-24
- 17 MAX=74, 001-05, 0106, 0107-08, 0109-11, 0112-14, 0115, 0116-18, 0119-22, 023, 024
- 18 0101, 0102-12, 0113-19, 020-24 (FOG AT RIVER)
- 19 001-10, 0113-24 (FOG AT RIVER)
- 20 0101, 0102, 0103, 0104-06, 0107-08, 0109-11, 0112-13, 0114-16, 0117-22, 023-24 HAZE VIS=5.6mi 22-23
- 21 001-06, 0107-08, 0109-12, 0113, 0114-18, 0119-22, 0121-23, 024; Gnd FOG/HAZE VIS=4mi 07, 6mi 08, HAZE VIS=6mi 09-10, 15-18, 22-23
- 22 001-03, 0103-04, 0105-06, 0107-08, 0109-12, 0113-16, 0117, 0118-19, 020, 021-22, 023-24, FOG/HAZE VIS=2mi 06, 2 1/2mi 07, 3mi 08, 4mi 09-11; HAZE VIS=4-5mi 12-17, 2mi 18-24.
- 23 RW--@ 1445, 0103-04, 0105-06, 0107, 0108-09, 0110, 0111-12, 0113-14, 0115-18, 0119-20, 0121-23, 024. FOG/HAZE VIS=2mi 03, 3/4mi 04, 1mi 05-06, 1 1/2mi 07, 1 1/2mi 08-09, 2 1/2mi 10; HAZE VIS=2mi 01-02, 3mi 11-21, 2 1/2-3mi 22-24
- 24 MAX=80, RW--@ 1100, 1400, RW--@ 1630E/1700, RW--@ 1700E/1715; 0101-04, 0105-06, 0107, 0108, 0109, 0110, 0111-13, 0114-16, 0117-18, 0119-20, 0121-23, 0124, 023, 024; HAZE VIS=5mi 05, 2 1/2mi 06, 3mi 07, 4mi 08-09, 5mi 10
- 25 MAX=78, MIN=69; RW--@ 1100E/1130, 0101-04, 0105-06, 0107-08, 0109-11, 0112-14, 0115-17, 0118-20, 0121-23, 0124, 023, 024. FOG/HAZE VIS=2 1/2mi 03, 2 1/2mi 04-05, 3mi 06-15, 4mi 16; SEA²=0.29; SWA²=0.13, DB=0.15
- 26 MAX=75, MIN=63; L-RW--@ 0530E/0730, FOG/HAZE VIS=1 1/2mi 07, 2 1/2mi 08, 3mi 09, 4mi 10; HAZE VIS=2 1/2mi 06, 6mi 11-13; 0101-02, 0103-04, 0105-06, 0107-08, 0109-11, 0112-14, 0115-17, 0118-20, 0121-23, 0124
- 27 FOG VIS=2 1/2mi 04, 1 1/2mi 05, 1 1/2mi 06, 1 1/2mi 07, 3/4mi 08-09; HAZE VIS=4mi 10-13, 11-20, 24; 0101-03, 0104-05, 0106-09, 0110-12, 0113-15, 0116-17, 0118, 0119-21, 0122-24
- 28 MAX=80, RW--@ 0645E/0715; FOG/HAZE VIS=4mi 02-05, 2 1/2mi 06, 3/4mi 07, 1 1/2mi 08, 2 1/2mi 09; HAZE VIS=5mi 10, 10; 0101-05, 0106, 0107-08, 0109-11, 0112, 0113, 0114-16, 0117-19, 0120-24 DB=.03, SWA²=0.06, SEA²=0.09
- 29 0101, 0102-04, 0105, 0106-08, 0109-11, 0112, 0113, 0114, 0115-20, 021-24
- 30 MAX=79, RW--@ 1430E/1530, THUNDER @ 1400; 001-05, 0106, 0107-08, 0109, 0110-11, 0112-14, 0115-18, 0119-20, 0121-23, 0124, 023, 024. FOG/HAZE VIS=4-5mi 17-21, 2-3mi 22-23, HAZE VIS=5mi 12, 1 1/2mi 24 SEA²=0.08 SWA²=0.08
- 31 TRW--@ 0800E/0245, (SEA² TRW @ 0215); TRW @ 1445E/1530, RW--@ 1300E/1345, FOG/HAZE VIS=3mi 06, 1 1/2mi 07, 1mi 08, 1 1/2mi 09, 2mi 10, 3mi 11; HAZE VIS=2-3mi 01-05, 5-6mi 13-14; 0101, 0102, 0103, 0104-06, 0107-08, 0109-11, 0112-14, 0115-17, 0118-20, 0121-23, 0124, 023, 024 SEA²=0.47 TRW @ 1445E/1530 SWA²=0.32, DB=.15

MPG 6462: SE=3130 Perwood, SW=1512 Oakton, DB=2316 Broomfield, DP=4041 Thompkins

ANN ARBOR, MICHIGAN, AUGUST 1977

19. RW-B1745E1815, FOG HAZE VIS 3mi.01, 1 1/2mi.02, 2 1/2mi.03-04, 8; HAZE VIS 5mi.05-07, 3mi.08-10, 4mi.11-13, 5mi.14, 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20-23, 0C24
20. MAX=69, MIN=57; RW-B045E-035, RW-B1045E1530, RW-B1530E1745, R-B1715E1745; HAZE VIS 5mi.07-08, 6mi.09-10, 4mi.11, 6mi.12-14, 4mi.15, 2 1/2mi.16, 5mi.17; 0A1, 0A2, 0A3, 0A4, 0A5, 0A6, 0A7, 0A8, 0A9, 0A10, 0A11, 0A12, 0A13, 0A14, 0A15, 0A16, 0A17, 0A18, 0A19, 0A20, 0A21, 0A22, 0A23, 0A24 PCP=SE=.33, EE=.53, SW=.52
21. 0A1, 0A2, 0A3, 0A4, 0A5, 0A6, 0A7, 0A8, 0A9, 0A10, 0A11, 0A12, 0A13, 0A14, 0A15, 0A16, 0A17, 0A18, 0A19, 0A20, 0A21, 0A22, 0A23, 0A24
22. MAX=75, RW-B000E1800, FOG HAZE VIS 3mi.07, 2mi.08-09, 2 1/2mi.10, 1 1/2mi.11, 2 1/2mi.12, 2mi.13, 1 1/2mi.14, 1mi.15, 1 1/2mi.16, 1mi.17, 1mi.18-21, 1 1/2mi.22, 2mi.23-24, HAZE VIS 5mi.05, 3mi.06; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24 PCP=SE=.03, EE=.04, SW=.04
23. TRW-B145E1720, TRW-B1430E1445, TRW-B1445E1545, RW-B1615E1715, RW-B1715E1745, FOG VIS 1 1/2mi.01-02, 4mi.03-05, 1 1/2mi.06, 1 1/2mi.07, 1 1/2mi.08-10, 1 1/2mi.11, 1mi.12, 2mi.13, 2 1/2mi.14, 2mi.15; HAZE VIS 5mi.16, 6mi.17, 4mi.18-20, 3mi.21-22, 5mi.23; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24 PCP=SE=.27, EE=.45, SW=.45
24. MIN=57, RW-B0400E0430, FOG VIS 3mi.03, 2mi.04, 1 1/2mi.05-07, 2mi.08-11, 2 1/2mi.12; 0A1, 0A2, 0A3, 0A4, 0A5, 0A6, 0A7, 0A8, 0A9, 0A10, 0A11, 0A12, 0A13, 0A14, 0A15, 0A16, 0A17, 0A18, 0A19, 0A20, 0A21, 0A22, 0A23, 0A24
25. FOG HAZE VIS 4mi.07-08; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24
26. JUNE RW-B1545E1820, RW-B1715E1845, FOG HAZE VIS 2 1/2mi.07, 3mi.08-10, HAZE VIS 6mi.11; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24
27. RW-B1745E1800, FOG HAZE VIS 3mi.05, 2mi.06, 2 1/2mi.07, 1 1/2mi.08-10, 4mi.11, 3mi.12; HAZE VIS 4mi.09, 3mi.13, 5mi.14-17, 4mi.18-20, 3mi.21, 5mi.22; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24
28. RW-B1730E1715, RW-B2115E1800, FOG HAZE VIS 2mi.01, 1 1/2mi.02, 3 1/2mi.03, 1 1/2mi.04-05, 1 1/2mi.06, 1 1/2mi.07, 1 1/2mi.08, 1 1/2mi.09, 1mi.10, 2mi.11, 3mi.12, 4mi.13, 6mi.14, 4mi.15, 5mi.16; HAZE VIS 3-5mi.13-20; 0A1, 0A2, 0A3, 0A4, 0A5, 0A6, 0A7, 0A8, 0A9, 0A10, 0A11, 0A12, 0A13, 0A14, 0A15, 0A16, 0A17, 0A18, 0A19, 0A20, 0A21, 0A22, 0A23, 0A24
29. RW-B1045E115B1200E1245, TRW-B1115E1145, (RW+OVER SEA-B1930E2000), TORNADO (MILAN) 1230, FOG VIS 5mi.01, 2mi.02-06, 1 1/2mi.07, 3mi.08, 2 1/2mi.09, 2mi.10-12, 2 1/2mi.13-14, 5mi.15; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24 PCP=SE=.21, EE=.04, SW=.06, CB=.02
30. FOG HAZE VIS 4mi.05, 2mi.06, 2 1/2mi.07, 1 1/2mi.08; HAZE VIS 5mi.09, 09-10; 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24
31. HAZE VIS 5mi.07-09, 0C1, 0C2, 0C3, 0C4, 0C5, 0C6, 0C7, 0C8, 0C9, 0C10, 0C11, 0C12, 0C13, 0C14, 0C15, 0C16, 0C17, 0C18, 0C19, 0C20, 0C21, 0C22, 0C23, 0C24 MAX=81

Precip. Gauge Location: SE 3130 FARMER
SW: 1513 DICKEN
EE: FIRST EXHAUSTING KNOT
CG: 2316 BROOKMAN

- 23 SCATTERED FROST AM, 001-17, ①Ac18, ①Cu19, ①Ac20-24, SE A° MIN = 35, WV = SE°/5.1 mph, AW = 6.0 mph
- 24 Fog Vis = 6 mi. 07, 061-04, ①C15, ①Ac06, ①Ac07-10, ①C11, ①C12-14, ①C17-19, ①C20-21, ①Ac22, ①Cu23, ①Ac24 WV = 147°/2.0 mph, AW = 5.1 mph, SE A° MIN = 37
- 25 17-24, RW = ①V0230, ①Ac01-03, ①Ac04, ①Ac05-06, ①Ac07, ①C08-13, ①Ac14-15, ①Cu16, ①Cu17-18, ①Ac19-21, ①C22-24 WV = 266°/4.7 mph, AW = 5.4 mph
- 26 001-24 WV = 269°/3.8 mph, AW = 4.9 mph, SE A° MIN = 42
- 27 Haze Vis = 5 mi. 21-24, 001-06, ①Ac07-08, ①C09-10, ①Ac14-14, -①C15-16, -①C17-24 WV = 174°/4.5 mph, AW = 5.4 mph, SE A° MIN = 42
- 28 Max = 69, Fog Vis = 2 1/2 mi. 07, 1 1/4 mi. 08, 1 1/2 mi. 09, 2 mi. 10, 2 3/4 mi. 11-14, 4 mi. 15, 2 mi. 22, 1 mi. 23-24, Fog/Haze Vis = 4 mi. 05-06, 4 mi. 21, Haze Vis = 4 mi. 16-18, 5 mi. 19-24, ①C01, ①C02-03, ①Ac04-06, -①C07, -①C08-10, -①C11-13, -①C14-15, ①Cu16, ①C20-23, -①C24 WV = 172°/3.4 mph, AW = 3.8 mph, SE A° MIN = 52
- 29 Fog Vis = 1 1/4 mi. 01, 3 mi. 02-04, 1 1/2 mi. 05, 1 1/2 mi. 06, 1 1/2 mi. 07, 1 1/2 mi. 08, 2 mi. 09, Haze Vis = 3 mi. 10, 4 mi. 11-12, 5 mi. 13-19, 6 mi. 20-21, 4 mi. 22-23, 5 mi. 24, -①C01, ①C02-04, ①C05-06, -①C07-11, ①C12, ①Cu13, ①Cu14, ①Cu15-17, ①C18-24 WV = 205°/3.8 mph, AW = 4.7 mph
- 30 Fog Vis = 3 mi. 01-02, 2 1/2 mi. 03-04, 2 mi. 05, 1 1/2 mi. 06-07, 1 mi. 08, 3 1/2 mi. 09, 1 1/2 mi. 10, Fog/Haze Vis = 2 1/2 mi. 24, Haze Vis = 2 1/2 mi. 11-13, 3 mi. 14, 4 mi. 15-18, 3 mi. 19-20, 4 mi. 21-23, -①C01-07, -①C08-10, -①C09-10, -①Ac11, -①Ac12-13, -①C14-15, -①C16-18, -①Ac16, -①Cu17-18, ①Cu19, ①Ac20, ①Cu21-24 WV = 292°/3.6 mph, AW = 4.9 mph, min 51

WV = MEAN DAILY WIND VECTOR

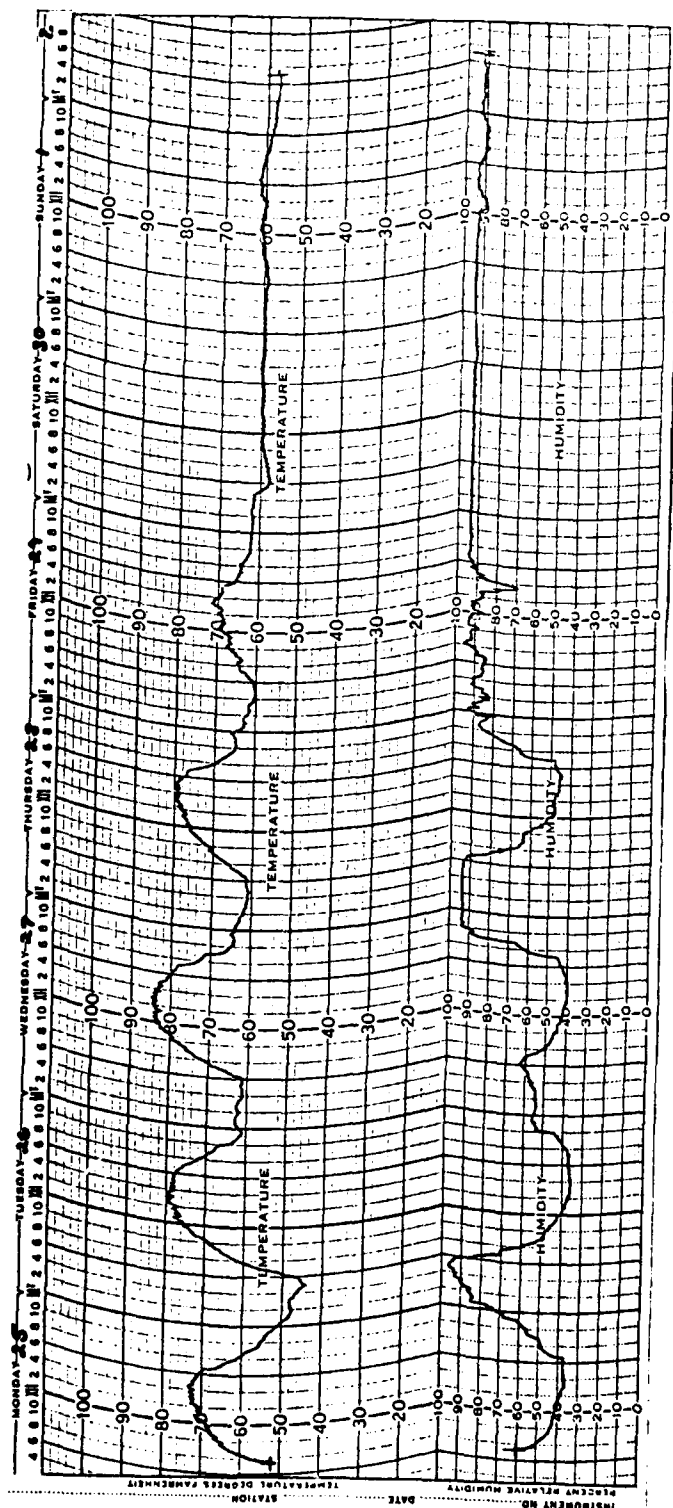
WS = MEAN DAILY WIND SPEED

PCP GAGE LOCATIONS SE = 3130 FERNWOOD
SW = 1513 DICKENS
EE = EAST ENGINEERING BLDG
RG = 2316 BROCKMAN

BECAUSE OF A GAGE CALIBRATION, THE AVERAGE WIND SPEEDS & VECTORS ARE IN ERROR

TO CORRECT THE ERROR, USE THE FOLLOWING FORMULA:

$$\text{Wind Speed (True)} = \text{Wind Speed (Gale)} * 1.32 + 0.11 \text{ (in mile/hour)}$$



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176 HOURS
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Figure B-2. Hygro-Thermograph Chart

(a) On: 25 June 1979, 0715 EST; Off: 2 July 1979, 0715 EST.

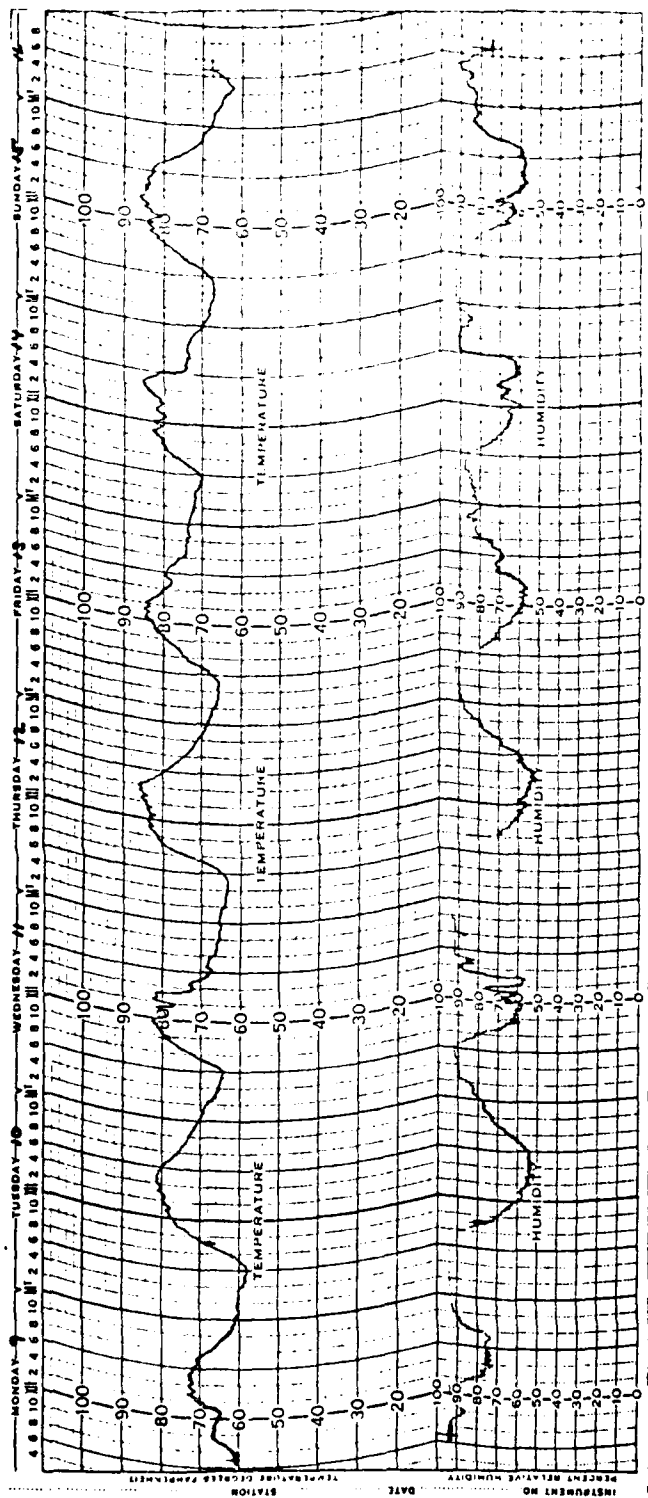


Figure B-2. Hygro-Thermograph Chart (Continued)

(c) On: 9 July 1979, 0645 EST; Off: 16 July 1979, 0700 EST.

HYGRO-THERMOGRAPH
176 HOURS
CHART NO. 5-207-W
OFF: 0645 EST, 9 July 79
BELFORT INSTRUMENT COMPANY
BALTIMORE, MARYLAND, U.S.A.

REFERENCES

1. A. Lawson, "Climatology of Selected Areas of West Germany Affecting Sensor Performance", ERIM Report 138300-23-T, June 1979.
2. A. Lawson, "Terrain Characteristics of Selected Areas of West Germany Affecting Sensor Performance", ERIM Report 138300-39-T, 1979.

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